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VOL 4 NO 40 OCTOBER 1961

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CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

SPECIAL FEATURES

Design of practical self-repairing computer systems
M. V. WILKES, F.R.S., of Cambridge University, makes some practical suggestions in a field where so far the discussion has been mostly theoretical 86

Input-output techniques in computer process control
Ferranti's P. G. CORRIN describes the equipment that takes electrical signals from the plant and produces binary numbers for the computer to handle 89

Production control and machine loading in a jobbing shop
Before describing a system built round a large digital computer, S. DEMCZYNSKI of de Havilland's discusses three main approaches to machine loading 94

Computers on show
The first British Electronic Computer Exhibition for three years takes place at Olympia, London, from 3–12 October 97

Progress in automatic language translation
Dr ANDREW D. BOOTH of London University reviews the situation in the light of last month's international conference at the National Physical Laboratory 103

The state of analogue computation
Fresh from the international meeting in Yugoslavia, R. J. A. PAUL of the College of Aeronautics, Cranfield, points out the few bright spots 106

New guide to adaptive control
Bellman's latest work on dynamic programming is reviewed by Professor J. H. WESTCOTT of Imperial College 108

Talking about automation
Dr DENIS TAYLOR of Plessey Nucleonics was at this year's British Association meeting, and found some interesting things to report 109

REGULAR FEATURES

Leader: Advance in good order 79

Viewpoint: Top people talk computers—*Percy A. Allaway, Leon Bagrit, John Bull, Lord Chandos, Sebastian Z. de Ferranti, T. C. Hudson and Sir Gordon Radley* 83

Control Survey—22: Computers *by R. J. A. Paul* facing 116

Data sheet—24: Definition of an equivalent time constant, *by P. G. Morgan* 117

Ideas applied . . . *to* temperature control of small furnaces—gas density measurement—control of slurries 110

Control in action: Temperature control for radar display system—Controlling the Blackburn Buccaneer—Pensions data handling in Newcastle—Furnace control at Automotive Products—Controlling v.t.o.l. aircraft 119

Look at America: Report on the 1961 Joint Automatic Control Conference 114

Looking ahead	4	News round-up	124	New for the user	131
Letters to the Editor	80	People in control	127	Publications received	136
Pick-off	118	Authors in *Control*	128	Book reviews	140

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LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

MONDAY 2—WEDNESDAY 11 OCTOBER
Business Efficiency Exhibition, Olympia. Details: Hart-Lidbury, Panton Ho., 25 Haymarket, S.W.1.

WEDNESDAY 4—THURSDAY 12 OCTOBER
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs S. S. Elliott, 64 Cannon St, E.C.4.

THURSDAY 5—FRIDAY 6 OCTOBER
Two-day export conference. Details: C. G. E. Parrot, Overseas Div., B.E.A.M.A., 36 Kingsway, W.C.2.

TUESDAY 10 OCTOBER
Trends in computer engineering by W. S. Elliott. (*I.E.E.*)

WEDNESDAY 11 OCTOBER
Papers on *Inertial navigation: general introduction of inertial navigation* by R. Collinson, and *Components and techniques employed in inertial navigation systems* by E. Bristowe. 7 p.m. School of Management Studies, Unity Street, Bristol. (*Brit.I.R.E.*)

Process control in paper mills by H. B. Whitehouse and M. E. MacLaurin. (*S.I.T.*)

SUNDAY 15–THURSDAY 19 OCTOBER
16th Engineering Conference (T.A.P.P.I.). Washington, D.C. Details: Technical Association of the Pulp and Paper Industry, 155 East 44th St, New York, 16, U.S.A.

TUESDAY 17 OCTOBER
The 1961 Sir Alfred Herbert Paper: *Finance for industrial growth* by D. L. Donne. 6.30 p.m. The Lecture Theatre, R.Ae.S. (*I.Prod.E.*)

WEDNESDAY 18 OCTOBER
Recent developments in mechanical transfer for machines and assembly by M. H. Bezier. Midland Hotel, Birmingham. (*I.Prod.E.*)

A symposium on *Digital differential analysers*. 6 p.m. London School of Hygiene and Tropical Medicine, Gower Street, W.C.1. (*Brit.I.R.E.*)

Pneumatic controls in industry by L. H. Kirk. Joint meeting with I.Mech. E., North Stafford Hotel, Stoke-on-Trent. Details: W. E. Darby, Stoke-on-Trent Assoc. of Engineers, 234 Victoria Road, Fenton, Stoke-on-Trent.

THURSDAY 19 OCTOBER
The Thomson Lecture: *The inspiration of science*, by Sir George Thomson at 6 p.m. at The Royal Institution. Admission by ticket only. (*S.I.T.*)

THURSDAY 19–FRIDAY 20 OCTOBER
A symposium on *Scale-up and pilot plants*. The Royal Overseas League, St James's, S.W.1. (*I.Chem.E.*)

MONDAY 23 OCTOBER
'*Is automation making satisfactory progress?*' An informal discussion opened by Prof. A. Tustin (*I.E.E.*)

MONDAY 23—FRIDAY 27 OCTOBER
Design Appreciation Courses for Engineers (Staff Course). Details: Press Office, Council of Industrial Design, 28 Haymarket, S.W.1.

TUESDAY 24 OCTOBER
A general method of digital network analysis particularly suitable for use with low-speed computers by M. N. John. *Digital computers in power system analysis* by P. P. Gupta and Prof. M. W. Humphrey Davis. The Engineers' Club, Manchester. (*I.E.E.*)

TUESDAY 24—THURSDAY 26 OCTOBER
National Conference of the British Institute of Management, Torquay. Details: Miss E. Ellett, 80 Fetter Lane, London, E.C.4.

WEDNESDAY 25 OCTOBER
Achieving high reliability in electronic equipment by N. B. Griffin. 6.45 p.m. University of Leicester. (*Brit.I.R.E.*)

Instruments for the first U.K. scout satellite by Prof. J. Sayers. 6.15 p.m. Electrical Engineering Department, Birmingham University. (*Brit.I.R.E.*)

TUESDAY 31 OCTOBER
Chairman's Address: *Trends in automation* by D. R. Hardy. 6.30 p.m. College of Further Education, Greenclose Lane, Loughborough. (*I.E.E.*)

TUESDAY 31 OCTOBER—FRIDAY 3 NOVEMBER
Effluent and Water Treatment Exhibition and Convention. Seymour Hall. Details: P. I. Craddock, Dale Reynolds Publicity, 2 Broad Street Place, E.C.2.

WEDNESDAY 1 NOVEMBER
Annual dinner of the I.Prod.E. Dorchester Hotel. Principal speaker will be The Rt Hon. Viscount Chandos. (*I.Prod.E.*).

FRIDAY 3—SATURDAY 4 NOVEMBER
Fourth Materials Handling Convention. Connaught Rooms, W.C.2. (*I.Prod.E.*)

MONDAY 6 NOVEMBER
Semi-conductor diodes and rectifiers in control engineering by P. R. Wynman and *The transistor in control engineering* by Dr G. D. Bergman. (*S.I.T.*)

WEDNESDAY 8—FRIDAY 10 NOVEMBER
Conference on *Non-destructive testing in electrical engineering*. (*I.E.E.*)

THURSDAY 9 NOVEMBER
Brains Trust on *Automatic control*. Inaugural Meeting of the Automatic Control Group. (*I.Mech.E.*)

MONDAY 13—SATURDAY 18 NOVEMBER
Second Engineering Materials and Design Exhibition and Conference. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

International Factory Equipment Exhibition. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

THURSDAY 16 NOVEMBER
Digital techniques for the study of sea waves, ship motion and similar processes by D. E. Cartwright, M. J. Tucker and Miss D. B. Catton. (*S.I.T.*)

MONDAY 20—FRIDAY 24 NOVEMBER
Design Appreciation Courses for Engineers (Staff Course). Details: Press Office, Council of Industrial Design, 28 Haymarket, S.W.1.

WEDNESDAY 22 NOVEMBER
A symposium on *Materials in space technology*. The Lecture Theatre, R.Ae.S. Details: The British Interplanetary Society, 12 Bessborough Gdns, S.W.1.

MONDAY 27 NOVEMBER—FRIDAY 1 DECEMBER
Design Appreciation Courses for Engineers (Executives Course). Details: Press Office, Council of Industrial Design, 28 Haymarket, S.W.1.

TUESDAY 28 NOVEMBER
Automatic plant analysis by electrochemical methods by R. F. Rodger. (*S.I.T.*)

WEDNESDAY 29—THURSDAY 30 NOVEMBER
A conference on *Oil hydraulic power transmission and control*. (*I.Mech.E.*)

THURSDAY 30 NOV.—FRIDAY 1 DEC.
A symposium on *Nuclear electronics*. (*I.E.E.*)

WEDNESDAY 13 DECEMBER
Application of complex plane methods to system design by P. K. M'Pherson. (*S.I.T.*)

WEDNESDAY 17—THURSDAY 18 JANUARY 1962
A symposium on *Electronic aids to banking*, under the aegis of B.C.A.C. Details: I.E.E.

MONDAY 22 JANUARY 1962
'Exposition meeting' on *Recent developments in automatic boiler control practice*. Details: R. J. Redding, 66 The Drive, Isleworth, Mddx. (*See also Control, July, p.* 122). (*S.I.T.*)

FRIDAY 16—TUESDAY 20 FEBRUARY 1962
Salon Internationale des Composants Electroniques. Parc des Expositions, Porte de Versailles. Details: S.D.S.A., 23 rue de Lubeck, Paris 16e, France.

APRIL 1962
'Exposition meeting' on *Self adaptive control systems*. Details and suggestions: R. H. Tizard, Whitterick, Ellesmere Rd, Weybridge, Surrey (*See also Control, July, p.* 122). (*S.I.T.*)

MONDAY 16—WEDNESDAY 18 APRIL 1962
The Second International Flight Test Instrumentation Symposium. College of Aeronautics, Cranfield. Details: M. A. Peary, The College of Aeronautics, Cranfield, Bletchley, Bucks.

WEDNESDAY 25 APRIL—FRIDAY 4 MAY 1962
Conférence Internationale des Arts Chimiques. Paris. Details: Maison de la Chimique, 28 bis rue Saint-Dominique, Paris 7e, France.

MONDAY 30 APRIL—FRIDAY 4 MAY 1962
Second International Compressed Air and Hydraulics Exhibition. Olympia. Details: W. G. H. Chesher, St Richard's Ho., Eversholt St, N.W.1.

TUESDAY 8—FRIDAY 18 MAY 1962
Mechanical Handling Exhibition. Earls Court. Details: H. A. Collman, Dorset Ho., Stamford St, S.E.1.

THURSDAY 31 MAY—THURSDAY 7 JUNE 1962
International Television Conference. Institution building, London. (*I.E.E.*).

WEDNESDAY 20—TUESDAY 26 JUNE 1962
Third Congress of the European Federation of Chemical Engineering. Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Sq., S.W.1.

MONDAY 16—FRIDAY 20 JULY, 1962
International conference on *The physics of semiconductors*. Exeter University. Details: The Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Sq., London, S.W.1.

TUESDAY 14—THURSDAY 16 AUGUST 1962
Conference on *Standards and electronic measurements*. Boulder Laboratories of the National Bureau of Standards. Details: J. M. Richardson, Radio Standards Laboratory, National Bureau of Standards, Boulder, Colo., U.S.A.

THURSDAY 15—TUESDAY 20 OCTOBER 1962
International Congress and Exhibition of Laboratory, Measurement and Automation Techniques in Chemistry (Ilmac). Swiss Industries Fair, Basle, Switzerland. Details: M. Trottmann, Foire Suisse, d'Echantillons Basle, Switzerland.

MONDAY 1—FRIDAY 5 JULY 1963
3rd Conference, International Federation of Operational Research Societies. Oslo University, Norway. Enquiries: Sir Charles Goodeve, International Federation of Operational Research Societies, 11 Park Lane, London, W.1.

SEPTEMBER 1963
Second congress of the International Federation of Automatic Control. (Ifac). Basle, Switzerland. Details: papers, B.C.A.C., c/o I.E.E.; general inquiries, Dr-Ing. G. Ruppel, Prinz-Georg-Strasse 79, Düsseldorf, Germany.

OCTOBER 1961 VOL. 4 NO. 40

CONTROL

Advance in good order

It is equally easy either to glorify or to debunk automatic computers. In some contexts the analogy with the brain comes so easily to mind that one is drawn irresistibly into fantasy, and perhaps fallacy. In other contexts one might think of the computer as merely an elaborate electronic camshaft: so regarded, its powers of ' decision ' appear to be fundamentally no more complex than those that determine the movement of cylinder valves in an internal combustion engine. (Look at some of Babbage's computing machinery in the Science Museum.) Perhaps the most important thing about modern computers is their speed, achieved because of the splendid force:inertia ratio that is available to electronic engineers.

The hard task is to be sensible about computers. They are nowhere near yet to their full development or exploitation. But, in urging this view upon the more phlegmatic managements, one can slip with dreadful facility into glib oversimplification. In just the same way as some enthusiasts have identified automation with the introduction of feedback, so others have identified it with the introduction of computers. These enthusiasts are like the proverbial tree-viewers, who inhabit a wood that they cannot see.

The best statement of the broad view is probably still to be found in the words of the mathematician Norbert Wiener, the father-figurer of cybernetics. In his book, *The human use of human beings*, published in the early fifties, Wiener wrote: ' The computing machine represents the centre of the automatic factory, but it will never be the whole factory . . . . it receives its detailed instructions from elements of the nature of sense organs. The sense-organ problem is not new, and it is already effectively solved. Besides these sense organs, the control system must contain effectors. Some of these are of a type already familiar . . . Some of them will have to be invented . . . The all-over system will correspond to the complete animal '. Wiener's perspective was obviously good, even if he did see his details too optimistically. (For example, the problems of on-line instrumentation for automatic control are not to this day ' effectively solved.) But Wiener himself, with all his penetrating insight, seems possibly to have been led too far by the notion that the computer is an *ersatz brain*.

The on-off variety of regulator is frequently described as the simplest and crudest kind of control; but, paradoxically, the comparable binary operation of a digital computer is often elevated to equality with the highest functions of the human intellect.

While it would be unscientific to predict that artificial brains will never be contrived, it would be foolish to assert that their contriving is already in sight. There is so much work waiting to be done, well in advance of any possible approach to synthetic thought. The so-called ' memories ' of computers are still relatively clumsy and inadequate things. Components must be made more reliable, and the introduction of some kind of redundancy has to be considered. Human styles of communication need time-taking translation before they can be handled by a machine—a versatile reading instrument, for instance, has still to be devised. And for every step of technical progress, money must be found and its investment justified.

The present issue of *Control* is rather a special one, concerning itself particularly with the design and use of computing systems and their component parts. In this leading article we have deliberately endeavoured to strike a balanced, restrained, and sobering note, because we think that the ensuing pages demonstrate how very much there is to get excited about. We do not wish to see any enthusiasm damped, however, but rather to see it effectively channelled. Once again, in these columns, we are led to deplore the lack of a public body or government department designed to help industry move more noticeably and effectively toward full automation. Especially in the rapidly advancing sector of computation and data processing, it is vitally important to catch up with the many opportunities that are being missed at this moment, and not to be misled by the more fanciful possibilities for the remoter future.

LETTERS to the EDITOR

Control at college . . .

SIR: I am about to embark on my final year of study for the B.Sc. degree in engineering and have recently read some of the articles in your magazine and a few of the more elementary textbooks on Control.

This reading has fired my interest but has left me uncertain about the function of a Control Engineer. Am I right in assuming that he is concerned with the design of equipment utilizing many types of devices (e.g. mechanical, electrical, hydraulic etc) and consequently requires a wide rather than specialised engineering background?

If my assumption is correct, will my degree which is nominally mechanical but with the maximum electrical bias through subsidiary subjects, provide adequate background or would I be advised to try and persuade the University authorities to allow me to take other electrical subjects normally unavailable to mechanical students?

Bournemouth, Hants W. GOSLING

● *We have invited Professor J. H. Westcott, of the Electrical Engineering Department at Imperial College, to give the required advice. He writes: 'Mr. Gosling's dilemma is a genuine one. It represents the thin edge of a thickish wedge as far as University authorities are concerned. By all means urge for a liberalisation of syllabuses, but I fear that it will be a very long time before this gets done. My advice to Mr. Gosling is to take the maximum breadth of syllabus in terms of electrical and hydraulic specialisations of an existing basically mechanical course. He will not be any worse off at the end of the course than the rest of us were and he will have the advantage of knowing full well that this is not going to be the end of the matter—for his real education in systems will still be to come.*

'Let me amplify what I mean by saying "he will not be worse off". Currently systems projects in the broad sense of the term involve considerations of electrical, hydraulic and pneumatic modes of energy transmission. A good systems firm would not wish to be committed à priori *in their design to any particular mode, so that in the initial assessment of a project a triumvirate of specialist engineers would consider the pros and cons of each mode of energy transmission and a decision would be made as to which mode was most appropriate. From that point onwards design would be in the hands of the experts of the chosen mode of energy transmission and a loose collaboration with the others would have to suffice in case of need for subsidiary aspects of the project. In the future we look forward to the replacement of the triumvirate by single minds. Mr. Gosling's generation have this possibility if we are prepared to help them achieve it. Mr. Gosling, as the first of many young men to follow, starts with the conception of a Control Engineer and asks what he does. He then enquires how he can best prepare himself for this profession. We should take his question seriously'.*—EDITOR

. . . and at home

SIR: I would refer to a review in a recent issue of *Control** on the home-study course dealing with "Automation", offered by the Capitol Radio Engineering Institute.

It would appear that your reviewer has, from the sample lessons submitted for review, made some generalisations on the course as a whole that may tend to be a little misleading.

The review refers to "—several pages on the elements of the calculus", and the deduction is made that mathematical knowledge is assumed. It should be pointed out that these pages occur in the introduction, are the only treatment of mathematics as a subject in the course, and are intended for revision only. The whole course is intended for the Senior Engineer with a good mathematical background who may, or may not, require the revision mentioned above.

I would consider that some assessment of the course as a medium for teaching the subject, would have been of value to your readers; e.g. the manner in which the subject is introduced, developed and finalised, the tasks that the student must undertake, and the type of examination tests that the student is set after each lesson.

The final paragraph of the review suggests that comparisons are being made between the course material and a book. Such a comparison cannot be made. Home-study lesson material will always appear to be "excessively wordy" when compared with a book. The student is obtaining a service when studying a new subject by correspondence. He is seeking the rapid assimilation of new facts, and requires explanations that are as complete as his standard of knowledge will allow.

May I suggest that a correspondence course cannot be reviewed adequately in a six-paragraph cover of a few lessons? To be fair to your reviewer he should have seen the whole course.

Finally, insufficient credit has been given to C.R.E.I. for providing a course that fulfills a very urgent need at the present time. Where else can the busy engineer (who may know very little of the subject) obtain a concise course on Automation that he can study at times convenient to his own industrial life?

Theydon Bois, Essex R. S. ROBERTS

● *Mr W. F. Lovering, who contributed the review in our July issue, writes: 'If my review is considered unfair because it was based upon a sample of the course and not upon the whole course, the fault must lie with those responsible for submitting the material for review.*

'Mr Roberts' statement that the pages on the elements of calculus occur in the introduction is not correct, the pages in fact, occur in the electrical assignment, number 1119 (Introduction to Computers) which is the 10th lesson in what is described as an advanced postgraduate course. If in fact, the course is intended for a senior engineer with a good mathematical background, this material which occupies 26 of the 45 pages of the introduction to computers lesson is clearly unnecessary. In this, as in other parts, it is difficult to estimate the market for which the course is intended.

'There is no doubt that a good deal of the material could be useful to many engineers to study on their own; however, there will also be others who would prefer a rather more brief and precise treatment'.—EDITOR

* July 1961, p. 123—EDITOR

VIEWPOINT *As the second Computer Exhibition is about to open . . .*

TOP PEOPLE TALK COMPUTERS

No room for neglect

THE RT HON. THE VISCOUNT CHANDOS, *Chairman, A.E.I. Ltd*

Computers were originally developed to help scientists: calculations could be made in a few hours which once would have taken a team weeks to complete.

Next, computers began to be used in aircraft navigation, machine tool and process control, and in the control of both thermal and nuclear power stations. Their part in saving inventory has become important.

Thirdly they were turned to the task of reducing clerical labour. With the increased size of industrial and commercial companies, the problems of administration become more complicated: the exchange of information has to be more elaborate, and central overhead expenses tend to increase. Costing assumes an even greater importance.

The range of reliable computers, and the ancillary equipment which is now available, give opportunities to management under all these three headings.

Close study will reveal how much the present strain on scientific and engineering staff can be relieved, how much more efficiently raw materials can be deployed on the shop floor, how much more closely they can be programmed and costed during the period of manufacture, and how the invoicing and collection of the finished product can be effected with less staff.

We can afford to neglect none of these: nor can we afford to use and adapt these new tools slowly.

Chandos

Transistors for the hurly-burly

PERCY A. ALLAWAY
Managing Director, E.M.I. Electronics Ltd

The computer of the immediate future is, by common consent, the transistor computer.

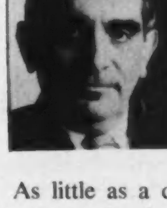
Applications range from helping keep your bacon and eggs fresh by maintaining a fine stock control at Sainsbury's to holding down bank charges at Barclays'—first British bank to use a computer for centralized branch book-keeping. The Ministry of Labour use one for calculating such statistics as the Retail Prices Index, and the first large transistor computer in this country to be used commercially was installed at Boot's Pure Drug Company last year for stock control and sales invoicing.

Other applications are just as varied and show the confidence of leading organizations. My company has shown its own faith in the computer as a business tool by installing one for payroll work, invoicing and calculating recording artistes' royalties in countries all over the world. When the Chancellor recently announced his intention to raise Purchase Tax, our computer calculated a new price list for 550 categories of gramophone record in 1min 45s.

The success of the transistor computer in the hurly-burly of modern office work can play a considerable part in maintaining this country's standard of living—by enabling British exporters to exercise tighter control over all aspects of their activities, and in that way improve their service while holding down prices.

The outlook for the transistor computer is bright—you can count on it!

P. A. Allaway



A hierarchy of machines

LEON BAGRIT
Deputy Chairman and Managing Director, Elliott-Automation Ltd

As little as a decade has seen electronic digital computers turn from a few laboratory-built equipments into a major industry. The early machines were used primarily for scientific and engineering calculations, and

they opened possibilities previously unthinkable. However, to the world at large they were no more than a scientific curiosity. By the middle of the decade there were some numbers being used by Universities and Government establishments, and their application to business data-handling was getting under way. These machines were all 'valve' computers, and frequently had to be switched off-the-air, as far as the user was concerned, for routine checking of valves in order to prevent break-down during normal use. Even so, break-down during use was not uncommon. The transistor has an expected reliability a thousand times that of a valve, and its use in computers has opened the way to true automation.

Spectacular as the use of computers for huge mathematical calculations or high-speed payrolls has been, its impact on society as a whole, as yet, is marginal. However, given a dynamic approach to the problem, the use of computers in integrated automation can truly revolutionize industry in the next ten years. There is a handful of systems running in the U.S.A., and even a few in this country, where the 'thinking ability' of the computer has been applied to process problems to improve quality and throughput save waste, and so on.

There are plans, but as yet no installations, to create a link between the processes of manufacture and the 'paper work' that controls them. In these plans the computer is treated as a component in the system, and a hierarchy of machines may be employed in a complete scheme. Equipment exists for this job and the appropriate technical effort is available. But what is now required is the will of Management and Government to use these techniques. The next ten years will see real automation in use throughout the industrial world. Let us hope that Britain will lead in this new industrial revolution.

Catch up with computers

JOHN BULL
Managing Director, I.C.T. Ltd

It is evident that the machine is ahead of human capacity to employ it to maximum advantage. Users may well be able to explain how the computer works, but not nearly so well able to harness it for solution of their own management problems. Hence, well to the forefront of current activity, is the critical study of applications. This study imposes on management itself the task of establishing, in each individual industry, what exactly *is* management information.

In the routine tasks of automatic data processing the electronic computer has many benefits to confer, notably in the speed with which it is able to dispose of those often voluminous calculating and recording commitments inseparable from present-day business. Here the trend is very definitely towards broadening the base of computer employment by introducing basic data into the system as soon as possible after their initiation, and by extending employment further towards the production of final management control information. This means more on-line data processing and the elimination, whenever possible, of intermediary steps outside the computer system. Accounting procedures will be further streamlined by automatic character-recognition equipment.

Perhaps the most important feature receiving attention is a 'common language' for computers. The concept of common-language machines is not new, and indeed the punched-card data-processing machine relies on the expressibility of data in a form readily comprehended by each machine in the system. But standardization of computer languages goes further than this, because it will permit readier interchange of function between computers of different origin, as well as reducing the manual labour of programming. The recent formation of a European Computer Manufacturers' Association, which has been recognized by the International Standards Organization, will result in agreed standards and the adoption of common-language principles.

Considerable attention is being devoted to increasing storage capacity while, at the same time, reducing size and increasing operational flexibility. Thin-magnetic-film storage seems to point the way towards a solution.

The future may bring more special-purpose computers. It will undoubtedly also bring a more scientific approach to the problems of management.

John Bull

Two turning points

SEBASTIAN Z. DE FERRANTI
Managing Director, Ferranti Ltd

The theme of the Second Electronic Computer Exhibition is, appropriately, the second generation of computers. It marks a turning point in design—we are no longer building computers with valves but are using transistors and other semiconductor devices. To me, this exhibition marks another turning point—in the utilization of computers.

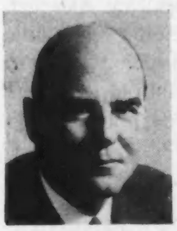
We are finding that the machines installed a few years ago are no longer adequate for the amount of work they have to do. The work has not only expanded in bulk but has spread into many new fields which were never envisaged when the computers were first installed. I am not saying that this is happening with every three- or four-year-old machine in operation, but the situation

undoubtedly exists, and numbers of people are already ordering replacement computers of increased power and capacity.

The pressure of work is perhaps most noticeable in computing service centres and other co-operative schemes, where many different users share the services of perhaps one machine. The universities, in particular, are having to work under these conditions because of the extremely rapid growth of demand for machine time arising from all departments—to say nothing of the demand arising from customers outside. One of my own company's service centres could easily be occupied, night and day, on the work of two or three clients—if it were allowed to be.

From the manufacturers' point of view, this turning point means that we have had to expand our development and production capacities so that we can now build computers costing several hundred-thousand pounds instead of several ten-thousand pounds. Indeed my own company is already about to make the step into the next higher bracket, of machines costing several million pounds each. These figures may seen rather frightening to people who are not familiar with the use of computers, but it is an economic fact that, the larger the machine purchased, the lower is the cost per computing operation.

Sebastian de Ferranti.



Mechanization is not enough

T. C. HUDSON
Managing Director, I.B.M. (U.K.) Ltd

To control an organization, management needs to know up-to-date facts. It must know today what is happening today: it needs also to know (based on today's facts) what is likely to happen tomorrow. This is not too difficult in the one-man business because that one man can know all that is going on at any time and then make decisions based on the relevant facts.

But in the more complex organization current facts are harder to obtain. Decisions, therefore, are likely to have an element of guess-work. Furthermore, facts are not normally available from a single source but are vested in departments. This leads to overlapping and duplication of effort as well as to delays, and the facts that reach management (sometimes contradictory) are likely to belong to the past rather than the present.

Electronic data processing equipment, and particularly the computer, provides management with a tool that makes full control possible, because it can process all the information of even the most complex organization and extract for management only those facts on which action must be taken at once. Such equipment will not control by itself, but will, through better processing, make it possible to do that which cannot otherwise be done through lack of time, method and manpower.

Yet electronic data processing equipment must be used correctly and by a skilled staff. Existing procedures must not simply be mechanized: they must be rethought and redesigned, otherwise the result will simply be to speed up the inadequate system that has grown up over the years. It is this rethinking that is now necessary if industry and commerce are to increase productivity.

A gap in public thinking

SIR GORDON RADLEY
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It is difficult to overestimate the effect which computers and data processing systems will have on the daily lives of us all. Almost every week we hear or read of some new application of electronic computing techniques by which the drudgery is taken out of a large-scale routine task, or some arduous series of calculations or taxing piece of overseeing is handed over from the man to the machine. The day when all the wearying or repetitive tasks in factory, office, laboratory—and home—will be done automatically is closer than is generally thought.

Very considerable advances have been made since 1958, when the last Computer Exhibition was held. For this reason the present Exhibition is well timed. It will give both the professional and lay man opportunity to assess the advances.

The transistor, and miniature circuits and components, used in this age to control vehicles in orbit and to guide supersonic aircraft and missiles, have now been brought into the office and factory. Computers and data processing systems are no longer the relatively large and clumsy machines that they were, suitable in so many cases only for large computer bureaux and research centres, but are understood and used by quite small concerns.

There is still a gap in the public's thinking as regards automatic routine work and control by electronic means. On the one hand it is regarded as something which replaces men and takes away their work. This is not so. It releases them, in a labour-starved community, for other, usually much more interesting work. On the other hand, computers are thought of as still something fairly vague in the future, at present used in ones and twos by the most go-ahead concerns. This is not true either. Computers are already doing our banking, catering, design engineering and many other ordinary tasks. We can put them to work more and more, to our very great advantage.

W. G. Radley.

Design of practical self-repairing computer systems

by **M. V. WILKES** F.R.S. *University of Cambridge*

The reliability of individual components cannot be indefinitely increased, and some failures must occur. A different approach seems to be needed if computers are soon to become dependable enough for really large on-line applications. Can computers be made to repair themselves? It is very difficult to meet the case by using redundant logical networks. Another way, which is proposed in this article, is to check the entire computer frequently with a test program, and to cut out any faulty units that are revealed. This raises practical problems, and practical suggestions are made here

A FACTOR SERIOUSLY LIMITING THE GENERAL ADOPTION of automatic control is the standard of reliability that can be achieved. This is especially so in the case of the more elaborate control systems based on the use of digital computers. The introduction of solid-state devices represented a marked step forward, and has led to a general improvement in reliability. It is easy, however, to think of applications which call for reliability of an altogether different order from anything that can be attained at the moment: examples are air traffic control and the control of chemical processes which are on the verge of instability.

There is a limit to what can be done by improving the reliability of individual components, and people have been asking whether it would not be possible to design computers that are in some sense self-repairing. Although this idea has now been canvassed for some years, little practical progress has been made. The subject has been discussed mostly from a theoretical point of view and I would like in this article to make a few practical suggestions.

General requirements

If a self-repairing system is to be useful in such applications as air traffic control it must satisfy the following requirements:

1 Faults should be detected before they have done any harm and should be cleared within a few seconds.

2 No information should be lost as a result of a fault, and the program should be automatically restarted at the point at which the fault occurred, or slightly earlier.

3 With the exception of a microscopic residue, the self-repairing feature must cover *all* possible faults. It must be possible to design the system so as to meet arbitrarily stringent requirements as regards the occurrence of simultaneous faults.

4 *Either* the machine must suffer no progressive degradation as a result of the occurrence of successive (self-corrected) faults, *or* means must be provided for measuring the amount of degradation that has occurred, and hence of ascertaining the degree of protection against break-down still existing.

The first alternative under **4** implies that the self-repairing feature must be backed up by a manual system

of replacing or repairing units that have developed faults. The manual work must not cause any interruption in the working of the system.

Error-correcting logical networks

Many attempts have been made to base the design of self-repairing computers on the use of redundant logical networks designed to perform correctly even though some of the components fail. None of these attempts have really succeeded, and I believe that there are grave difficulties to be overcome if this line of approach is to be successful. Some of these are as follows:

1 It would be difficult to be sure that *all* faults (except for the microscopic residue referred to above) were covered by the correcting system. Any theoretical demonstration that this was the case would require assumptions about the behaviour of the elements under fault conditions, and practical elements might not behave in the way postulated; for example, binary switching elements might cease to behave in a binary manner when they became faulty, and as a result abnormal potentials existing in some part of the network might be communicated to other parts and cause faulty operation over a wide area.

2 It would be very difficult to estimate the degree of degradation that had taken place otherwise than by isolating and testing the individual units.

The above remarks refer to logical circuits intended for computing and control purposes, and do not apply with the same force to circuits for the storage and transmission of information; here error-correcting circuits used with redundant codes have an undoubted future.

Systems based on fault detection by test programs

The remainder of this note will be concerned with systems in which the correct working of an entire computer is verified at frequent intervals by the performance of a test program, or by the successful completion of checks incorporated in the operational program. When faulty operation is discovered the fault is cleared by the elimination from the computer of the faulty unit. The problem is, of course, to devise a practical way of performing the latter operation.

One must guard against the assumption that one has only 'hard' faults to deal with. By hard faults I mean faults which put a unit permanently out of action in a well defined manner; examples are faults due to an open-circuited resistor or a completely broken connexion. Such faults are easy to locate, and can often be pin-pointed to a particular package by a test program; if it were made a specific design objective, the machine could no doubt be designed in such a way that quite a large proportion of hard faults could be located in this way.

Unfortunately one has also to deal with marginal faults, program-sensitive faults, and intermittent faults. Sometimes one is faced with the situation in which a group of units refuses to work together, although individual units work perfectly well in combination with others. The more troublesome faults under this group of headings frequently defy positive diagnosis, and are only eliminated after a wide-spread replacement of units.

In a recent Letter to the Editor of *I.R.E. Transactions on Electronic Computers*, I outlined a system in which the switching of elements was done electronically. In fact no distinction was made between logical elements which might form part of the computer, and those which might be used to connect the units of the computer together, all the available elements forming part of a random connected (or partially ordered) logical net. In the present stage of technology there would be little chance of making a practical system along these lines. For a practical system it is probably best to think in terms of packages such as are used in conventional computers, each package containing one or two-flip-flops together with their associated gates.

Switching systems for inter-changing units

It is in the design of a switching system for interchanging units that one of the principal difficulties arises. Under present circumstances it appears that mechanical switching is necessary, since only in this way can one be sure that faulty units will be properly isolated. Different forms of mechanical switching that suggest themselves are:

1 Relays.
2 Multi-contact rotary or cam-operated switches.
3 A mechanized version of the ordinary system, whereby units are plugged and unplugged.

It should be noted that the self-repairing feature extends to cover intermittent contacts in the switching system.

Relays are not generally thought to be sufficiently reliable for use in computing systems. This is certainly the case when they are clicking away all the time. However, in the present suggested application, the relays would operate only rarely, and sporadic faulty action would be automatically neutralized. Moreover, there is some reason to believe that modern sealed reed-type relays set a new standard of performance.

System **3** would present an interesting problem in mechanical design, and is not wholly to be ruled out although it suffers from obvious disadvantages. In particular, it would be slow, and therefore of use only if one could be sure of tracing the fault to one of a small number of units (see the next section). An advantage would be that it would be possible to arrange for units to be subjected to an automatic test on the way to or from the rack in which they were stored.

Closely connected with the choice of a switching system is the question of the *availability* of each unit held in stock in relation to a particular position in the computer. In the ordinary manual system of main-

tenance there is full availability; that is, any spare unit of the right type can go into any socket in the computer. On the other hand, one might have a system in which two units were allocated to each position in the machine with a set of relays for changing over. This would provide a much lower degree of availability in that only two out of the total number of units existing could be switched to a particular position.

Deciding which units are to be changed

If a fault can be located by the test program, supplemented by any built-in checking circuits that might be provided, to a single unit it can be cleared by substituting another unit for the one indicated. The latter can then be sent for testing and repair before it is returned to stock. A similar procedure can be used if the fault can be located within a small number of units. Not all faults can be located as definitely as this, however, even if they are hard faults and, as pointed out above, the situation is still more difficult if they are of an intermittent or program-sensitive nature. In such circumstances a possible procedure would be to withdraw all units from the computer, or from that section in which the fault was known to lie, return them to stock, and then withdraw at random a net of units for insertion into the computer, no distinction being made between units that had just been returned and units that had been previously in stock. This procedure would be repeated as many times as necessary for a working computer to be obtained. A record would be kept of the packages used on each occasion, and a subsequent analysis made. Any packages which were found to occur an abnormal number of times in selections which did not produce a working computer would be withdrawn for examination. An improvement could perhaps be made by selecting units, not at random, but according to some cyclic system under which each unit appeared in the computer an equal number of times in each cycle.

If information is available about the state of readiness of units in stock, then some, at any rate, of the trial and error implicit in the procedure described above can be avoided. One possibility would be for units held in stock to be given, either automatically or manually, a periodic check on a testing device. This would permit the majority of units in which hard faults existed to be identified and removed for repair. However, units that worked under test would not necessarily work in the computer. If a proportion of computer time could be spared for the purpose, selected units from stock could be switched, individually or in groups, into the computer for testing. It might be possible in this way for there to be designated a 'shadow computer' made up of spare units which had been tried in the computer and found to work together. This would mean that, with a high probability, service could be restored very rapidly after a break-down. It would, however, require that a large number—more than 100%—of spare units would have to be available.

A somewhat different approach may be made to the problem of locating the offending unit or units when a break-down occurs by having two computers running side by side on the same program and in synchronism. When a program test failed, comparison of wave-forms in the two computers would in principle permit the fault to be pin-pointed. Rather elaborate equipment would be required to perform these comparisons automatically, and it is difficult to see how this equipment could easily be brought within the self-repairing scheme. This approach to the diagnosis problem might, however, be suitable for a system in which the repair of faults took place semi-automatically,

In evaluating a system for clearing faults by replacement of units, regard must be had to the length of time taken to ascertain by test program that a computer is serviceable. Most hard faults would, no doubt, make themselves felt quickly, but the same is not true of intermittent and program-sensitive faults.

Control of the self-repairing organization

Some of the procedures referred to in the last section are quite elaborate, and to perform them automatically would take the full resources of a digital computer. An attractive possibility would be for the complete system to consist of two distinct computers, each capable of taking the operational load and also capable of supervising the maintenance of the other. One great advantage of this scheme would be that very nearly the whole of the equipment required for supervisory purposes would be brought within the ambit of the self-repairing feature. A careful analysis would be required of the risks attendant on simultaneous break-down in the two computers, and of emergency procedures which could be adopted if this happened. The risks would be much reduced if the shadow-computer idea were adopted, and it were arranged that, when a fault occurred on either computer, the setting up of the corresponding shadow computer was a 'fail-safe' operation.

I pointed out earlier that it would be necessary to back up the self-repairing system with manual maintenance. In a fully automatic scheme, the operational records would be analysed and printed automatically, and all that the maintenance engineer would have to do would be to remove for inspection any units that were indicated as being faulty or suspect. In less automatic schemes, more in the way of analysis and on-line testing might be required of the maintenance engineer.

The idea that the failure of a check—such as a programmed arithmetic check, or a parity check—should lead to an automatic repetition, or initiate some other remedial procedure, has become very familiar to those working with digital computers. If the same principle could be applied to the whole computer, instead of to parts of it, then the dream of the self-repairing computer might one day be realized.

Reference
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How the electrical signals from a plant are converted into binary numbers that can be handled by the controlling computer

Input-output techniques in computer process control

by **P. G. CORRIN,** *Ferranti Ltd*

THE AIM OF PROCESS CONTROL BY COMPUTER IS TO improve the efficiency of the process; to accomplish this the relevant plant information must be read into the computer, and the computer output used either to guide the plant operator where control is manual, or to control the plant directly. The plant conditions will usually be described in terms of widely different variables, such as temperature, pressure, gas concentration and so on, and transducers are used to produce electrical signals representing the plant variables, the signals then being routed to the computer installation. This article describes the equipment which accepts these electrical signals to produce binary numbers compatible with the computer number system, and which makes use of the computer output to provide a logged record or plant control signals.

A digital computer accepts only one number at a time, but there will be many input signals derived from the plant. The input equipment must therefore be capable of selecting these signals in some desired sequence. If this were a simple, regular one, then a uniselector or its electronic equivalent could be used; this procedure is not usually adopted, however, for either the computer program must be arranged to use the particular input information immediately it is selected, or the information must be read into the computer store, to be used as required at some later time by the program. The timing conditions imposed on the program in the first arrangement reduce its flexibility, while a large amount of storage capacity is used up in the second. The usual technique is to allocate to each input an address similar to that used to describe storage locations inside the computer; a given input is selected with a program order specifying the address, which is decoded to close the desired selection switch.

Types of input and output

The electrical input signals obtained from the transducers will in general require to be converted into binary numbers which can be accepted by the computer input register, the form of the converter depending on that of the input signal.

Probably the most common type of input is that of a continuously variable d.c. signal, although the source impedance and full-scale output voltage vary enormously for different types of transducer; for instance, a thermocouple might have an impedance of 10Ω, and produce a no-load output of 20mV, whereas the electronic force-feedback type of transmitter can drive a current of the order of 15mA into a load of several kilohms. An analogue-to-digital converter is required in both cases, but the thermocouple output must be amplified before conversion. Since analogue signals can contain spurious ripple components, smoothing may also be required.

On the other hand, the signal may be in discrete, or digital, form; an example is the output of a limit switch on a control valve, indicating that the valve has reached the end of its travel. This may be considered as a single-digit binary number, defining one of two states of the valve. The position of the valve may be defined more precisely if more digits are used; thus, ten bits would specify the position to one part in 1024 (2^{10}). This type of output is obtained from optical shaft-digitizers used to measure mechanical rotation, the output digits appearing on parallel channels. While the output number could in principle be a direct binary representation of the shaft rotation, in practice this coding can lead to large errors, arising as a result of misalignments in the reading heads, and a cyclic progressive code is usually adopted, in which only one digit of the output number changes for a unit increment of rotation. A logical conversion is therefore necessary.

The relative usefulness of analogue and digital pick-offs depends to a large degree on the accuracy requirements, but, for the orders of accuracy associated with most plant control problems, analogue methods are generally more economical, bearing in mind also that an

analogue signal uses one input channel, whereas the output of an n-bit digitizer uses n channels.

Output signals may again be classified broadly into analogue and digital; analogue, to be used as the input to chart recorders or devices such as electropneumatic control valves, and digital, as the input to typewriters or solenoid-operated valves.

The computer produces one output number at a time, but there may be many plant control points requiring computer information. The program must therefore be arranged to produce in sequence in the computer output register the information relevant to each point, and facilities must be provided for routing this information to the appropriate channel. This is just the inverse of input selection, and requires the same type of address decoding and switching systems. An additional facility which may be needed is that of storage, for the information relevant to a given control point appears only for a short time in the computer output register during the output sequence; where a continuous signal must be applied to a plant instrument, the latest output value must be stored in the channel.

Address decoding

A given input is selected with a program order specifying the input address, and this address must be decoded to operate the appropriate input selection switch. The principles are best illustrated by an example. Suppose, for instance, that the address is described by four binary digits, so that sixteen addresses could be specified. Thus, input number 0 would be addressed as 0000, number 1 as 0001, and so on up to number 15, 1111. When the order containing this input address is obeyed, voltages representing the four address digits appear on four parallel channels. If these voltages are fed to a four-input *and* gate (Fig. 1) the output voltage of the gate corresponds to a '1' only when each of the input voltages corresponds to '1', that is, when input 15 is specified. This output is therefore used to close switch 15.

Selection switch 14 is operated with the output of a gate of which the four inputs are the three most significant digits of the address, together with the inverse of the fourth least significant. When the least significant digit is '0' its inverse is '1', so that when address 1110 appears, the input voltages to the gate each correspond to '1'.

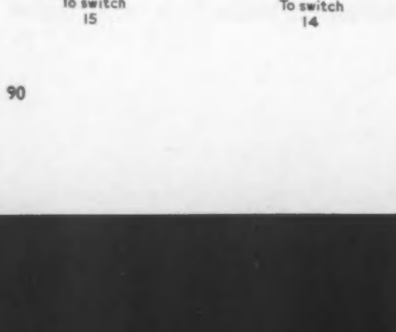

Fig. 1 Address decoding

The extension of the principle to cover all the selection switches results in a system in which each switch is driven from an *and* gate, the inputs to the gates representing the various combinations of normal- and inverted-address digits.

This system, although straightforward, is not usually the most economical in components, and an alternative is illustrated in Fig. 2.

Denoting the digits of the four-bit address considered above by A, B, C and D, and their inverses by A', B', C' and D', and supposing that each of four two-input *and* gates is fed with one of the combinations of A or A' with B or B', that four more gates are similarly fed

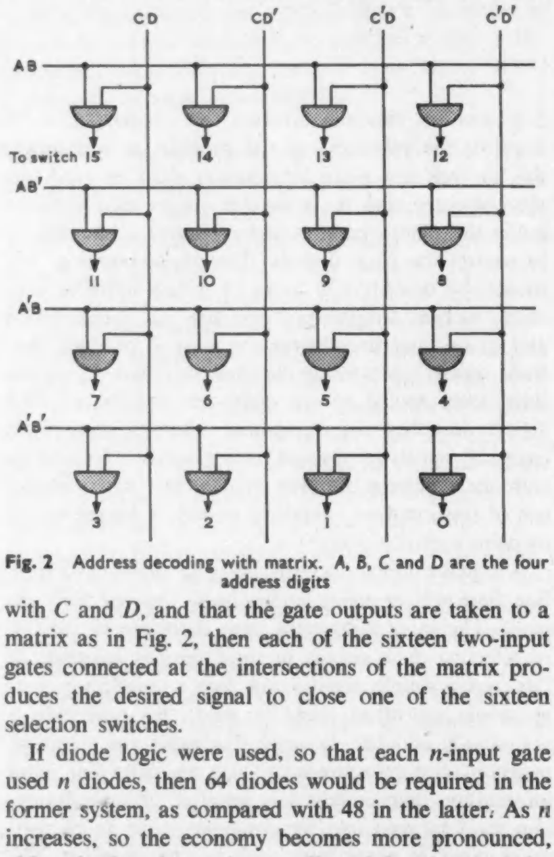

Fig. 2 Address decoding with matrix. A, B, C and D are the four address digits

with C and D, and that the gate outputs are taken to a matrix as in Fig. 2, then each of the sixteen two-input gates connected at the intersections of the matrix produces the desired signal to close one of the sixteen selection switches.

If diode logic were used, so that each n-input gate used n diodes, then 64 diodes would be required in the former system, as compared with 48 in the latter. As n increases, so the economy becomes more pronounced, although the picture is complicated by the need for buffer units between the levels of diode logic.

Switches

The address decoder sends a signal to operate a particular selection switch; the form this switch takes, however, depends on that of the input itself.

Where the input is digital, selection can be made with logical elements, such as the *and* gate. For analogue signals, however, the properties of the switch must approach those of an ideal switch, which presents zero impedance to the signal when closed, infinite impedance when open, and allows no leakage between the signal

controlling the switch and that controlled by the switch.

The choice of switch lies broadly between electromechanical and semiconductor types. In general, the impedance and leakage characteristics of the electromechanical switch approach more closely to the ideal than do those of the semiconductor, but the comparatively short life and lower operating speed can be considerable disadvantages.

The operating life of a relay is very dependent on the current carried by its contacts; at low currents contamination can take place, giving rise to a permanent open-circuit. This effect may be overcome in sealed relays by such techniques as the inclusion of a 'getter' to absorb impurities in the relay atmosphere, or the use of mercury-wetted contacts. A life expectancy of at least 10^9 operations is claimed for a relay of this latter type, although the operating time is comparatively long, of the order of 6ms.

The operating time is governed by the inertia of the armature and by contact bounce; a design in which these are minimized uses a pair of magnetic-reed contacts sealed into a glass tube and operated by an external magnetic field. The operating time is limited by the rate of rise of the external field, but times of the order of 150μs are claimed to be possible using special techniques.

The influence of operating life on the choice of switch depends very considerably on the rate at which any given input is sampled, which may vary in different installations from something of the order of ten times per second to perhaps once every ten minutes. Working on a twenty-four hour day, a relay with a life of 10^9 operations would last about three years at the former sampling rate, an impracticably short life in an installation involving several hundred relays. On the other hand, about 18,000 years would be required to complete the 10^9 operations at the lower rate.

The switching delay in the relay limits the maximum rate at which inputs can be read in, for evidently if n inputs are scanned using relays with an operating speed of τ seconds, and fed to a single converter, then each input is read in once every $n\tau$ seconds. If this is not a sufficiently high rate then an increase may be obtained by grouping the inputs into several blocks, and feeding the output from each block to a separate converter. The final stage of the selection is then performed on the digital converter outputs, using logical elements working at the computer clock rate. Although this multiplies the sampling rate of any input by the number of blocks, it also increases the cost of the system, and complicates the program.

With semiconductor switches, on the other hand, operating speeds of a few microseconds are readily achieved, but not without some sacrifice; in the 'on' state, the incremental impedance of the switch is considerably higher than that which is obtained through a pair of mechanical contacts, and there may be a standing voltage across the switch for zero input current. In the 'off' state quite appreciable leakage currents may occur.

In the simpler types of switch, interaction can exist between the signal controlling the switch and the controlled current, in contrast to the virtually complete separation obtained between the current through the coil and that through the contacts of an electromechanical relay.

Consider, for example, the diode switch of Fig. 3, shown in the 'on' state. The standing diode currents are defined by the voltage V and resistance R, and serve

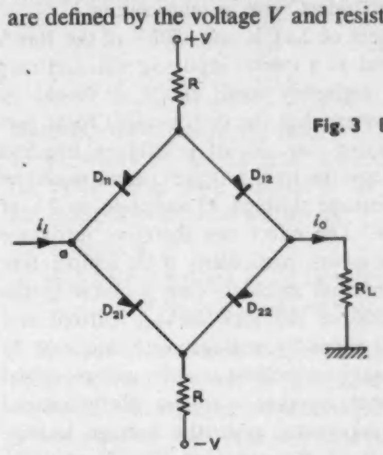

Fig. 3 Diode switch

to bias the diodes forward to give low incremental resistance R_d. If it is assumed that a diode can be represented by a resistance R_d in series with a voltage generator Δ, and that R_d and Δ remain constant, then it may be shown for the switch that

$$i_0 = \frac{i_i}{1 + \dfrac{r + 2R_L}{R}} + \frac{(\Delta_{22} - \Delta_{12})}{R}$$

Thus, the switch introduces an attenuation, which is reduced by making R large compared with R_d and R_L, and also introduces a spurious component which depends on the mismatch of diodes D_{12} and D_{22}. If the voltage at point a is examined, it is found to consist of a component due to the voltage drop across the load, another due to the diode resistances, and a third given approximately by the sum of $(\Delta_{12}-\Delta_{22})$ and $(\Delta_{11}-\Delta_{21})$. The effect of this voltage is illustrated by considering the case where an input current of 10mA is derived from a p.d. of 10V driving through a resistance of 1kΩ; assuming a spread in diode forward voltage of about 200mV at a forward current of 10mA, then the voltage appearing at a could be of this order. The input current would be no longer exactly 10mA, but could vary from this by as much as 2%; this error could be reduced if diodes were selected, but it is not possible to match characteristics over a range of currents and a mismatch of possibly 50mV would be about the best to be expected.

The action of the switch is controlled by the voltages $\pm$V; if these are not exactly of the same magnitude, or if the current-defining resistances R are not equal, then

a spurious component is introduced into the output current. In other words, the degree of isolation is determined by the accuracy of V and R.

The switch can be turned off by reversing the sign of V, so that the diodes become reverse-biased and the incremental resistances very high. The diode current does not, unfortunately, tend to zero, but to a temperature-dependent reverse saturation current; an average value for this current is in the region of 2μA at 25°C for germanium components, and this approximately doubles for every 10degC rise in temperature.

A leakage current of 2μA is only 0·02% of the 10mA previously assumed as a typical input current, and may appear to be a negligibly small effect; it should be remembered, however, that the switch might form part of an array selecting one out of possibly a hundred inputs, in which case the total leakage current would be the sum of the leakage through 99 switches, or 2% of the signal current. The effect can therefore introduce quite considerable errors, particularly if the temperature rises above the normal ambient. One solution to the problem is to measure the total leakage current and compensate for it either by analogue techniques or by making the necessary corrections to the numbers stored inside the computer; another is to use silicon instead of germanium components, since the average leakage current in these is of the order of 10mμA at 25°C. The leakage is reduced by several orders of magnitude, but the voltage drop across the switch is adversely affected; at 10mA forward current the average forward voltage of a silicon junction diode is 800mV, with a spread of about 300mV, as against 400mV and 200mV respectively for a germanium diode.

Transistor switches

The voltage drop across the diode switch can be an embarrassment; transistor switches, however, offer a considerable improvement in this respect. Thus, as the transistor base current is made increasingly more negative in the circuit of Fig. 4, so the collector voltage rises towards earth until the base-collector diode becomes forward-biased and the transistor acts as a closed switch. It may be shown that if, in a uniform base transistor, the resistance of the collector and emitter regions is negligibly small, then

$$V_{ce} \rightarrow -\frac{kT}{q} \cdot \frac{1}{\beta_i}$$

as $$i_b \rightarrow -\infty$$

If the transistor is inverted by interchanging the connexions to collector and emitter, then

$$V_{ce} \rightarrow -\frac{kT}{q}\,\frac{1}{\beta_n}$$

At room temperature kT/q is of the order of 26mV, so that with a β_n of thirty, V_{ce} approaches a limit of about a millivolt; in fact, V_{ce} is very nearly equal to this limit when the base current is of the same magnitude as the collector current. These expressions hold true for germanium alloy transistors, and very low values of V_{ce} can be obtained even with collector currents of the order of 10mA, provided a sufficiently large base drive is used.

In silicon transistors, however, the collector and emitter region resistances have an appreciable effect, and low values of V_{ce} are not easily obtained. In a non-symmetrical transistor an appreciable V_{ce} may be found for zero collector current, depending on the base drive, and the ratio of rate of change of V_{ce} with I_c is of the order of 5–10Ω. The first of these effects can be mitigated by using two transistors in a back-to-back configuration, and it is usually possible to compensate in the analogue circuits for the appreciable switch resistance. The advantage obtained in low leakage currents can outweigh these additional complications, and the silicon transistor switch is in fact a very useful device.

In Fig. 4 the transistor switches the zero-impedance supply E into the load R_L; the load current is defined by E and R_L, and only by the base current insofar as it affects V_{ce}. In general, however, the switch will be required to act between a high-impedance trransducer and the load, so that the base current must be balanced by introducing and equal and opposite current into the

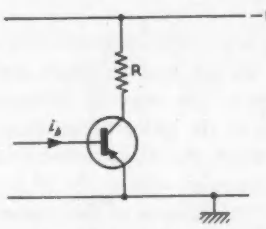

Fig. 4 Transistor switch

system, either with current-defining resistors or by using a transformer-coupled base drive circuit.

The leakage currents in a transistor switch are of the same magnitude as those in diodes, and the same considerations apply.

In general, a semiconductor switch of one type or another can usually be found except where very low signals such as thermocouple outputs must be switched with high accuracy. In these exceptional cases, either the signal must be amplified before selection, or high-quality relays must be used.

Conversion methods

The two conversions to be considered are analogue-to-digital, and cyclic progressive into true binary.

The basic units of an analogue-to-digital converter are illustrated in Fig. 5, which shows a four-bit converter arranged to deal with input currents in the range 0–16mA. The single bit stores S_0 to S_3 are arranged so that a '1' in a store closes the associated switch and allows current to flow through the appropriate resistance to the reference supply, V. The resistances are arranged in binary progression, so that if the contents of the stores are adjusted to balance the total resistance current i_R against the input current i_{in} then the number formed

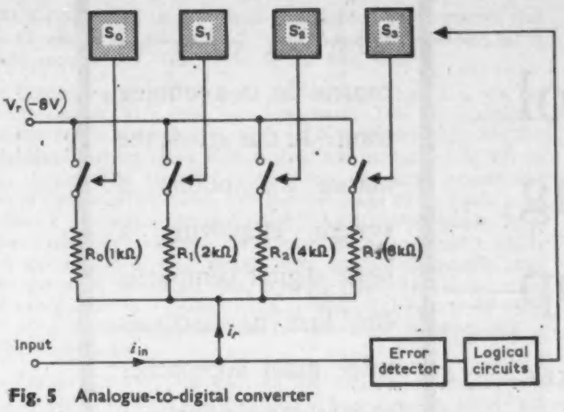

Fig. 5 Analogue-to-digital converter

from the store contents is the binary representation of the input current.

The most common method of setting up the stores may be described as a method of successive approximations. The stores are initially set to '0'; on the first step of the conversion cycle S_0 is set to '1'. On the next step S_1 is set to '1', and S_0 either reset to '0' or allowed to remain at '1', depending on the sign of the error-detector output resulting from the first step. The sequence continues until the difference between i_{in} and i_R is less than one half of the smallest quantum of current, in this case one half of $V/8R_0$.

The lowest value of this quantum is set by the discrimination of the error-detector; the accuracy of the converter as a whole depends not only on this but on the stability of the resistances and the reference voltage. An overall accuracy of 0·1% can be expected from production units using solid-state switches, working over normal ambient temperature ranges, and 0·01% has been achieved under more closely controlled conditions. It is worth while noting that the current i_R is the analogue of the number contained in the stores. If therefore the output number of the computer is set into the stores, and i_R fed to a low-impedance source such as the input of a feedback amplifier, instead of being compared with an input current, then the output of the amplifier will produce the voltage analogue of the digital computer output.

It may be necessary to smooth the analogue signal before conversion. This can take place after selection, so that only one smoothing filter is required, but the filter introduces a very considerable time-lag; time must be allowed after selecting an input for the filter output to reach its steady state. For instance, if it is required to attenuate a 50c/s component by a factor of ten, using a simple lag network, then 0·15s must be allowed after selecting an input for the filter output to come even within 1% of its steady value. Where high sampling rates are required, smoothing must take place before selection, with a filter in each input channel.

The other conversion system commonly encountered is logical conversion of the cyclic progressive code of digitizer outputs to the normal binary. The condition that only one digit of the digitizer output should change for one increment of shaft rotation does not define a unique code, but that usually adopted for its economy and ease of conversion is illustrated below for a three-bit output number.

DECIMAL NUMBER	BINARY NUMBER	CYCLIC PROGRESSIVE
0	000	000
1	001	001
2	010	011
3	011	010
4	100	110
5	101	111
6	110	101
7	111	100

Denoting the digits of the binary coded number by B_n to B_0, where B_n is the most significant, and those of the cyclic progressive number by R_n to R_0, the rules for conversion may be written as:

B_n equals R_n

B_{n-i-1} is 0 if B_{n-i} and R_{n-i-1} are both 1 or both 0

B_{n-i-1} is 1 if B_{n-i} and R_{n-i-1} are not both 1 or both 0

The conversion could be performed by the computer program, but this would be slow since at least one order time would be required for each digit, and the operation is best done at clock rate in a separate converter unit.

Output storage

It has been noted previously that means may have to be provided for storing information on output channels, in the situation where a plant instrument or recorder requires an uninterrupted signal. An on-off signal to operate a relay or solenoid can be held in a single-bit store such as a bistable circuit; analogue signals, on the other hand, are not so convenient, and are generally treated in one of two ways.

The first of these is to store, not the analogue signal, but its binary equivalent, using a separate register for each signal. The analogues are obtained through digital-to-analogue converters on each register. This is an expensive procedure, and the alternative is to store the analogue signals directly. Methods have been devised for this, using potentiometers driven from conventional servo-mechanisms, or stepping motors, but these suffer from the comparative lack of reliability associated with all equipment containing mechanical moving parts. Electronic clamp circuits appear to offer the most satisfactory solution, in spite of the limited holding times which can be achieved.

It is evident that digital output is the most convenient to store; another aspect in which it is the more attractive is that of power-handling capacity. Because either the current through, or voltage across, a transistor switch is small, quite considerable power output may be switched; transistors are currently available to handle currents of up to 25A, and p.d.s of up to several hundred volts.

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Production control and machine loading in a jobbing shop

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PART 1

What can production control do in a jobbing shop? In this article the author will outline a system employing a large digital computer. But first he discusses three main approaches to machine loading

THE AIM OF 'PRODUCTION' IS ALWAYS TO TRANSFORM initially given materials into more valuable products by performing a succession of specified operations. Depending on the pattern and volume of the flow of materials through the successive operational facilities, several kinds of production can be distinguished. One of them is the jobbing-shop type of production, characterized by the following features:

(1) **a** Manufacture of any product is undertaken in response to the customer's order (as opposed to production of saleable stocks).

b Many different products are manufactured and the batch quantities for each product are generally small.

c The different items are produced using the same operational facilities in various sequences, generally different for each type of item. As each item should be produced with the minimum delay, it competes with other items for the use of generally limited facilities.

The aims of production control are to:

(2) **a** formulate plans for manufacturing procedures,
b issue corresponding orders to various departments of the factory, and
c monitor execution of orders at every stage, and, if necessary, modify future planning and ordering accordingly.

The guiding principle of production control ought to be stated as a top-management policy-decision: e.g. minimization of manufacturing costs, or optimization of machine utilization, or minimization of work-in-progress capital, etc. It appears that the most rational and all-inclusive objective for production control is the maximization of the rate of return on the capital allocated for the general purpose of fulfilling customers' orders.

The usual assumptions about starting data for production control of a jobbing shop are:

(3) **a** Items to be manufactured; their quantities and due dates are known from the accepted orders. A departure from this is to undertake certain activities in response to *anticipated* orders.

b Manufacturing facilities are given. These include types and numbers of machines on the shop floor, quality and quantity of labour available, length of working day, availability of overtime, night-shift and subcontracting facilities.

c Design of each final product is known and complete. This includes knowledge of assembling methods, quantity and types of parts going into successive assembly stages and the division between b.o.f. (bought out finished) and m.h. (made here). For the latter, the raw materials are specified in kind and quantity; the operations to be performed on each part are determined in terms of: sequence, type of machine and labour to be employed at each operation, length of machine operation and tools to be used, specifications for corresponding set-ups, including their times, the necessary jigs, gauges, etc. Certain operations may be subcontracted for technical reasons.

d Stock positions of raw materials, finished parts, sub-assemblies, and final products are known.

e Orders already placed for b.o.f. and subcontracting work are known.

f Existing work-in-progress on the shop floor is known in terms of quantities and types of parts and assemblies, and of the estimated machine load required for the completion of the above.

The last three points arise from the fact that, as a rule, any new production control scheme is going to be imposed on a factory already in operation, for at least some time. Consideration of a scheme applicable only to a new jobbing factory, just about to begin work, is, in the writer's opinion, rather unpractical. Even so, there seems to be a contradiction between (3)a and (3)d, e, f because, if the factory produces only to customers' order, the existing stocks and quantities on order, both in b.o.f. and m.h., must have been already allocated to the past customers' orders, outside the scope of a new production control scheme, and therefore they ought to be neglected, apart from the resulting machine load needed for their completion. However, owing to the scrap allowance, bulk buying and economical batch sizes, there is no exact correspondence between requirements arising directly from customers' orders and actual quantities produced, bought, or placed on order. These discrepancies can build up to substantial amounts over a long period and must be taken into consideration in production planning at all times.

Applying now (2)a to (3), the main duties of production control are:

(4) a From (3)a, c, the total quantitative requirements, for b.o.f. and m.h. parts, arising from all customers' orders taken into account, are determined on the time scale.

b Comparing results obtained in (4)a with (3)d, e, f, the net requirements, with dates, are computed. The pre-established batch size is taken into account in these calculations, but the decisions, arising from bulk buying, are probably best left to the buyer. The expected delivery date for parts ordered, the rules for scrap allowance and the minimum stock levels enter also at this stage. At this point subcontracting results from top-level policy decisions, or arises from the technical inability of the shop to produce certain parts, which consequently must be made by somebody else in every case. The decision on another kind of subcontracting, arising at times from overloading of the shop, is taken at the later stage, when scheduling the machine load.

c Using (4)b and (3)b, c, f, all the required machining and assembly operations are scheduled. The manner in which this scheduling is performed, the length of the period covered by scheduling, the level of detail included, the rigidity of the resulting time-table, and the limits of human decision on the shop floor, constitute the fundamental differences between various types of machine loading schemes.

d On the basis of results obtained in (4)b, c, and using the information contained in (3)c, the orders for the shop and subcontractors are issued. New machinery and additional labour are requested, if necessary (this means a modification to assumption (3)b). The delivery schedule for b.o.f. parts and raw material, with dates, is issued to the buyer. The requests, with dates, for tools, gauges, drawings, etc, are made.

e As the work progresses, the results are reported at short time intervals to the production control centre, which modifies future plans, either automatically, according to pre-established rules, or by human intervention, and issues new orders accordingly. The amount of this corrective feedback and flexibility of control depends mainly on the type of machine loading scheme used in (4)c.

The computations arising from (4)a seem easy, but they may be complicated in practice by several stages of sub-assembling on certain products. A given part must be ready when needed; for the starting date of assembly, say. This date depends on assembly scheduling, which, in turn, depends on the total amount of work in the assembly shop. Hence, if detailed scheduling of work in the assembly shop is required, it has to be done before stating the delivery date for components, which would be troublesome in multi-stage operations. The situation is further complicated by the fact that similar components required for different assemblies must be produced in batches to reduce the amount of setting.

In (4)b the batch size, which usually depends, among other factors, on the machine load schedule produced in (4)c, is assumed to be fixed in advance, for reasons discussed later.

The main difficulty lies, of course, in (4)c, and, related to it, (4)e; comparatively speaking, (4)d seems to be easy.

One must always keep in mind that the above (seemingly) neat outline of production planning is much complicated by many factors, a few of which are: (i) the manufacturing of tools, necessary for machine operation, is in itself a complete production planning and machine loading problem in miniature; (ii) certain departments in the factory must be able to request the shop to manufacture at short notice some equipment needed for testing or research: this upsets the planned machine load; (iii) the actual amount of scrap may exceed the allowance on certain batches, and new batches must be rushed through the shop to be ready for the assembling date; (iv) certain quantities of parts must be re-worked, adding to the planned machine load.

Perhaps the biggest headache is given by modifications, which necessitate continuous up-dating of master files, and, if numerous, may upset any plans for the machine loading, buying and subcontract work, for obvious reasons. Also, the modifications will increase the volume of master files because the original information must not be erased, as it may be needed for manufacture of spares according to old standards.

There will always be literally hundreds of other complications peculiar to each particular jobbing factory. The production planning scheme covering all the foreseeable events is best presented by flow charts, and these should be prepared for each factory under consideration. The problem of machine loading, which is the source of the main difficulties in jobbing-shop production, will be discussed below.

MACHINE LOADING SCHEMES

The general principle of production planning, the maximum rate of return on capital employed, ought also to be the basis of any machine loading scheme. Guided by this, the optimum compromise between the following, generally contradictory objectives, must be achieved.

(5) a The capital tied up in work-in-progress, both on the shop floor and in stocks, must be minimized.

b The gross level of production should preferably be evened out over a long period, providing for stability in employment and in the amount of required machine facilities on the floor.

c The load in each machine class should exhibit the minimum of peaks and troughs, in order to reduce the costly overtime, night-shift and idle time (the reduction of the latter is equivalent to maximization of machine utilization).

d The total penalty for being late with deliveries to the customers must be minimized.

The weight attached to each of the above objectives can be best established by an investigation of operational-research type, or, as a short cut, ought to be stated as a top-management decision.

It must be said at the outset that, in the present stage of research, no satisfactory solution to machine load scheduling, fully taking into account all the above objectives, exists for the jobbing shop. Actual factories are so complex that, even if represented by models simplified to the point of becoming unrealistic, no complete mathematical answer to the problem of scheduling exists. All existing approaches to production control in a jobbing shop may be divided into three main groups.

(6) a The 'heap' approach, or shortage control.

b The statistical approach.

c The deterministic approach.

These will now be discussed in turn.

Shortage control

This approach derives support from the fact that, as so many unforeseen things can happen on the shop floor, the whole idea of planning may seem ridiculous. It is manifestly impossible to take everything into account, almost anything can happen, and usually does, so why bother to plan at all? Let us instead prepare broad theoretical plans for progress, then put to the shop as many orders as possible, loading every facility to the full capacity. Let us then check the availability of parts at fixed time intervals before assembling dates, and chase the shortages. In practice, this means working to the shortage list. However, it must be remembered that certain batches can be rushed only at the expense of delaying others (this sounds almost naïvely simple, but, unfortunately, it is not always understood). As a result of panic-chasing, the priorities mount up, making the task of shop supervision progressively more difficult. Although, it must be confessed, many—or even the majority—of large jobbing shops work essentially in this fashion and somehow survive, even make profits, there is little doubt that this approach is not to be applauded.

Statistical approach

This method consists of attempting to describe the system in statistical terms and to suggest procedures leading to improvements. In the first stage, the system is considered as given and emphasis is entirely on description, in a manner similar to the way in which one would study the motion of large aggregates of molecules, or the life of wild species of plants and animals, etc. The description, although it does not immediately lead to the improvement of the system, nevertheless enables the management to make more accurate predictions for the future. In the second stage certain suggestions are made, concerning changes of some parameters of the shop which would lead to improvement of its performance.

The statistical approach has certainly some advantages.

(7) **a** In every real shop there are many disturbing factors which must be neglected in any, not unduly complex, deterministic formula. The statistical description, by taking into account the summary effect of all these factors on certain vital aspects of the shop's performance, is usually nearer to real life.

b The accuracy of the model can be successively improved and checked without upsetting the normal operations of the shop.

c The statistical approach is more in line with indeterminism, which permeates the very basis of modern science. The old, rigid, mechanical models were overthrown long ago, and now, at best, are considered as approximations, appropriate in certain cases to the summary effects of basic, probablistic processes.

Yet there are two main objections to the statistical approach, each of which seems to be sufficient to rule it out as far as we are concerned.

The first objection is that mathematical queueing theory is not yet nearly sufficiently developed to be applicable to such a complex unit as a jobbing shop. This theory is sufficient for the treatment of simple cases, like specifying the economically optimum number of parallel servicing facilities, assuming simple distributions for random servicing times and random arrivals of units to be served. It is *not* very useful in dealing with scheduling problems in random conditions of complicated multi-stage networks of servicing stations. It is true that, under certain simplified assumptions, the jobbing shop can be considered as a collection of independent queues, each with a stationary distribution of waiting times. This has been proved both theoretically and experimentally: but it is doubtful whether the underlying assumptions are sufficiently realistic; and, even if they are, the prospects of suggesting improvements on this basis are rather slender.

The second objection is that in a jobbing type of production several activities must be synchronized for successful completion of each machining operation (delivery of materials, drawings, gauges, jigs, tools, etc.). Hence, it seems essential to state the target date for everybody concerned, and it is doubtful whether sufficiently accurate predictions could be made on the basis of statistical studies.

The deterministic approach

The underlying philosophy of this method is the exact opposite of shortage control. It is assumed that production can be planned beforehand, and that these plans are meaningful in the sense that they can be realized with reasonable accuracy.

Assuming now that all kinds of data enumerated in (3) are accurately known, an attempt is made to produce a schedule, including all future machining operations and being the economical optimum compromise of (5). It is obvious, heuristically, that a schedule resulting in a decrease of the amount of work-in-progress is likely also to increase the amount of overtime. A schedule aiming at a high degree of machine utilization is likely to aggravate bottlenecks and late deliveries. If all the necessary data are available and the objectives stated, including their comparative weights, it is not difficult to produce on a large computer the great number of complete schedules of future operations and evaluate each of them in turn. One might hope to find the optimum schedule in this way. At this point, the (so far) insurmountable difficulties arise. Assuming that we have to schedule the work of six machines on seven parts, each part having one operation on each machine, the number of possible schedules is $(7!)^6$. A computer capable of 50,000 complete schedules per second, together with their evaluations, which is several orders faster than any existing machine, would take approximately 10,000 million years to run through all possible schedules. This is more than some estimates of the period elapsed since the beginning of the universe.

To be continued

What to see at the
Electronic Computer Exhibition
National Hall, Olympia, London
3-12 October

Computers on show

DURING THE THREE YEARS SINCE THE LAST MAJOR EXHIBITION of computers, electronic data processing has become accepted, if not yet commonplace. The machines themselves are much improved, both electrically and mechanically, their logic systems have in many instances been simplified making for ease of operation, programming and maintenance, and they are considerably more reliable. This latter virtue stems of course from the increasing use of semiconductor circuits, the transistor being inherently longer-lived than the thermionic valve. Semiconductors dissipate much less power than valves and are considerably smaller, and so transistorized machines are more compact than their predecessors.

Other trends of recent years include those toward the ferrite store, the increasing use of magnetic tape, improved input/output devices, computers capable of 'time-sharing' (doing more than one job at a time), random-access storage, modular construction which permits a complex system to be built up from a number of standard units, character recognition and so on.

Possibly one of the most exciting developments is the process-control computer, and the next few years should certainly show industrial plants operating under the control of in-line computers. In the business world, integrated data processing is growing apace: this is already in semi-operation by various large organizations (the banks have at last made a start on it) and clerical automation (in general, a simpler problem than process control) should grow rapidly.

Digital computers

All the well known manufacturers of digital computers are exhibiting their products at Olympia. The salient features of these machines (analogue as well as digital) are presented in the pull-out chart facing page 116 of this issue of *Control*.

The Electronic Apparatus Division of Associated Electrical Industries (stand 15) are showing the **A.E.I. 1010** transistorized digital machine which, although small, can process a great deal of data and can control up to 32 peripheral units simultaneously. The A.E.I. 1010 has been so designed that A.E.I. feel it should be able to work with any future type of equipment The company have recently received a £250,000 order from the Scottish Division of the National Coal Board for a fully integrated system based on the A.E.I. 1010.

The Anglo-French concern, De La Rue Bull Machines (stand 25) are showing publicly for the first time their **300 D.P.** series of business-data processing equipment in computer form. This comprises a series of units each of which performs a prime processing task at high speed. A number of units may be connected to a master program unit which, itself, may be linked to a similar group. Materials scheduling and chain-store invoicing are demonstrated. A scale model of the very large **Gamma 60** data-processing system is also on show.

The transistorized **Emidec 1100** of E.M.I. Electronics (stand 2) is being shown in full operation, demonstrating the programs concerned with B.M.C.'s Longbridge factory payroll, stock control at the Admiralty stores, Copenacre, sales invoicing for E.M.I. Records, and typical hire-service applications. The installation includes a four-bay computing unit containing a 16,000-word drum, control console, power supply, five magnetic-tape decks, paper-tape punch and teleprinter paper-tape reader, card punch and reader and 600 line/min printer. A small air-cooling and filtering plant has beeen installed to handle the air-conditioning problem, and there is a high-speed data link with Automatic Telephone and Electric's stand (19).

Elliott-Automation (Elliott Bros. and Panellit) are sharing a large—over 3000 ft² area—(stand 14) with National Cash Register. The latest version of the **National-Elliott 803** solid-state general-purpose computer is being demonstrated working on a variety of commercial, scientific and industrial problems, so illustrating the machine's versatility. *Control* understands that seventy 803's had been sold up to August this year. The latest version is not only faster but incorporates a battery power-supply to compensate for mains fluctuations and failures. One innovation is a paper-tape station grouping together all input and output devices in a single unit. The immediate-access ferrite-core store can be backed by up to four magnetic-film storage units, and punched-card input and output facilities are also available. The 803 is being demonstrated carrying out a simplex linear program which calculates the optimum blending for a chemical production process.

A full-scale model of the **Elliott 503** gives an impression of the size and capabilities of this new machine. Nearly 100 times faster than the 803 it retains program compatibility with the latter, allowing the use of the established program library; it can also employ an Algol 60 autocode compiler.

Panellit are demonstrating the **609 industrial information and computing system** which is already in on-line operation in various industries. Based on the 803, the system can scan 1000 or more points and print a record of conditions throughout the plant. This information can be used for direct automatic control. The 609 is demonstrating a variety of routine control operations associated with the running of continuous manufacturing processes.

Elliott's Special Computing Division is demonstrating the 803 in five on-line applications: air traffic control, including the filing of flight plans; the simulation of aircraft movement with a plan-position-indicator display; the simulation of aircraft interception with a p.p.i. display; an automatic telegraph switching centre for a closed communications network; an airline seat-reservation system.

On the same stand (14) National Cash Register have a representational display of the new **N.C.R. 315** business data-processing system which has already been ordered by Leicester Permanent Building Society, Hertfordshire County Council, and several commercial firms. The 315 has an unusual memory system, 'Cram', which stores information on magnetic cards for random and sequential processing. These cards are held in cartridges each storing over 5,000,000 alpha-numeric characters; up to sixteen Cram units can be coupled to a 315, giving immediate access to any one of 88,000,000 characters.

National Cash are also exhibiting their new **N.C.R. 390**, a compact and inexpensive general-purpose system employing magnetic ledger cards holding up to 200 characters per card.

English Electric's latest work in the field of solid-state computers and d.p. systems is highlighted on stand 9. Three systems are on show for the first time: the **KDP10**, the company's main medium/large commercial system, **KDF9**, the very-high-speed general-purpose system, and the new **KDN2** process-control and general-purpose machine. The main displays thus fall into three sections, and include operational magnetic-tape units, a card reader operating in conjunction with a tape unit, and an automatic printer fed by another tape unit—all being suitable for both the KDP10 and the KDF9. Also on show are a KDP10 console, high-speed store, and tape store, and a KDF9 high-speed tape reader. English Electric's work in commercial fields (e.g. Midland Bank, Commercial Union Group of Insurance companies, and the Yorkshire Electricity Board) is emphasized.

The basic model of the KDN2 general-purpose digital machine costs around £20,000 and is suitable for such applications as the direct control of industrial processes, scanning and recording of temperatures and 'slave' work for such large systems as the KDF9 and KDP10. Its logical circuitry is provided by **Datapacs** designed on the building-block principle which can cover over seventy different logical functions to build up any system of data handling or control. The main store is a transistor-driven ferrite-core matrix extendable in increments of 512 18-bit words up to 4096 words.

A Datapac data logger, which is understood to have been in continuous operation over a long period at English Electric, Kidsgrove, is also shown, and some applications of **Deuce** are illustrated.

Ferranti (stand 8) have, of course, a great deal to show. **Sirius** is a small transistorized computer designed for ease of use. Its features are decimal notation and display, controls of the desk-machine type, and the fact that it can be plugged into an ordinary domestic mains supply.

Argus is the transistorized machine intended for the direct control of industrial processes. I.C.I. have ordered one for a chemical plant in Fleetwood, and Babcock and Wilcox intend using one for automatic start-up and shut-down of a 200MW boiler in the C.E.G.B.'s new West Thurrock power station. Argus is shown working with a model plant.

Atlas, possibly the world's most powerful machine, is now being installed at Manchester University. This general-purpose large-capacity high-speed computer is represented at the exhibition by its control desk, although a scale model is also shown. Atlas incorporates a supervisory system for regulating the flow of work through the machine, a 'page address' system for the efficient use of storage space, a new semi-permanent store for data frequently required, and an adder with exceptionally fast carry-over. It is rumoured that Ferranti will shortly sign a contract with London University for an Atlas.

Ferranti are also showing scale models of the **Apollo** and **Orion** computers. The high-speed, transistorized, Apollo is intended for the automation of flow processes and will handle a large number of input and output channels. One such machine is now installed at the Oceanic Area Control Centre, Prestwick, where it will be used for experimenting in automatic processing of data for air traffic control over the North Atlantic.

Little hardware is being shown by Honeywell Controls (stand 7) although the American **Honeywell 800** and **400** systems are illustrated on their stand. The 800 is a medium-to-large system having an extensive library of programs, and offering computer-controlled multi-program processing. The smaller 400 system utilizes the same peripheral equipment as the 800, with which it has tape and programming compatibility. Honeywell's Special Systems Division is demonstrating data scanning, display and control.

I.B.M. United Kingdom Ltd (stand 11) have an **I.B.M. 1620** data processing system which provides up to 60,000 positions of magnetic-core storage. Although primarily intended for the scientific and engineering work being demonstrated on the stand, the 1620 is suitable, with off-line listing of output cards, for many commercial applications. Input and output is alpha-numeric on punched cards, by typewriter and punched tape.

An **I.B.M. 1401 Ramac** system with high-speed tape units is also on show. This is a transistorized stored-program computer which is available in a wide range of configurations for both commercial and scientific use. It has up to 16,000 positions of core-storage and up to six high-speed magnetic-tape units. The Ramac disk store has a capacity of 20,000,000 characters of information immediately accessible in random order.

The new **I.C.T. 1301** is being shown in public for the first time by International Computers and Tabulators (stand 21). The transistorized 1301 operates with punched-card and/or magnetic-tape input and output as well as printed output at 600 line/min. The rate of program-controlled punched-card input is 600 cards/min and up to eight magnetic-tape decks can be incorporated in the system. Two magnetic-tape systems are available—the standard system (½in tape operating at 22,500 digits/s) and the high-speed system (1in tape operating at 90,000 digits/s). An immediate-access core store has a basic capacity of 400 words, each of twelve digits, and is capable of being expanded to 2000 words in multiples of 400 words. This is backed by a drum-store holding 12,000 words of twelve digits and extendable to hold up to 96,000 words in multiples of 12,000.

The **I.C.T. 1202** is also being demonstrated. This will illustrate an accounting procedure carried out by a French multiple grocer, L'Economie Bretonne.

Part of Leo Computer's fastest machine to date, **Leo III**, is on view on stand 43. This transistorized computer reads and records on magnetic tape, printing out at over 50,000 lines/h. A high-speed Anelex printer forming part of the new system is being demonstrated, as are a magnetic-tape transport and a paper-tape reader linked with an input assembler working at 1000 characters/s. It is understood that visitors to Leo Computer's stand who wish to see a Leo in operation may be invited to visit an installation.

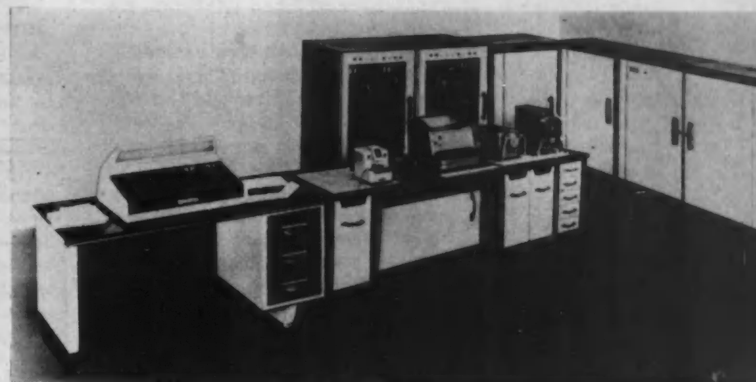
A transistorized **Stantec** system is, of course, the principal exhibit by Standard Telephones and Cables (stand 5). The central processer is itself a complete computer costing under £30,000, and this can be extended to suit any user's requirements. Based on the earlier **Stantec Zebra**, the latest system will handle programs developed for the Zebra, although the new machines have a built-in multiplication unit and a fast-access ferrite store. A simple machine code,

Top left: The A.E.I. 1010 computer in use at A.E.I.'s Computer Centre, at Sale, Cheshire.

Bottom left: Typical installation of De La Rue Bull Machines' 300 DP business-data processing system

Top right: The latest version of the National-Elliott 1803 solid-state machine

Bottom right: An Emidec 1100 computer used by the J. Sainsbury grocery chain for stock control and central accounting for supplies to branches.



'Seal' (standard electric accounting language), has been developed.

Data transmission

Many of the firms with computer interests are concerned with data transmission in one form or another. S.T. & C. (stand 5—see above) have their stand connected by a P.O. line to a Stantec in Harlow, Essex, and demonstrate both the transmission of data over the telephone network and remote data processing. S.T. & C., incidentally, have received a £2·5m contract for the first part of a £4·5m automatic electronic seat-reservation system for B.E.A. An earlier system for B.O.A.C., which is now being installed in London, operates like one supplied to S.A.S. by Standard Electrik Lorenz, A.G., of Stuttgart, an S.T. & C. associate.

Another S.T. & C. associate, Creed & Company (stand 26), possibly best known for teleprinters, are showing an integrated data-handling system for automatic order recording and invoicing. This is based on **Doris**, the electromechanical data handler developed for Shell-Mex and B.P. The new system is shown in relation to the ordering of spare parts by telephone. The input is by teleprinter and this brings a random-access punched-tape store into operation, the complete information being fed automatically to output machines. As demonstrated, four outputs are employed, three 100 word/min teleprinters (one assumed to be in a remote factory), and a tape punch. The basic system demonstrated is capable of handling one order of average complexity every two minutes, and is priced from £6000.

Data transmission is, of course, the prime function of the Post Office (stand 46), and the P.O. is exhibiting communications services suitable for transmitting data and explaining how they may best be used. At low speeds (up to 50 bits/s) equipment for preparing, transmitting and receiving punched-paper tape using the standard five-unit code may be rented or, with P.O. approval, privately owned terminal equipment may be used. Data can also be transmitted over the public Telex network and the P.O. is demonstrating a method of detecting transmission errors. Speech-type circuits are normally available for high-speed transmission (above 500 bits/s) and these offer speeds up to 2000 bits/s. Higher speeds require circuits of higher quality and special arrangements are necessary. Using P.O.-approved terminal equipment it is possible to transmit data over the public telephone networks at speeds up to 600 bits/s.

A demonstration of high-speed punched-tape input and output data-transmission systems is being given by Automatic Telephone and Electric on stand 19. Three transmitting terminals are working through an automatic telephone exchange to receiving terminals on stands 2, 9 and 43 (E.M.I., English Electric and Leo, respectively). These systems meet requirements in respect of the five-, six-, seven- or eight-unit code to be transmitted, the type of line

or radio circuit over which the equipment has to operate, the error rates which can be tolerated by the user, and the type of modulation and the transmission speed. Alternative methods of modulation and transmission speeds of 750, 1500 and 2400 c/s are available.

Low-speed data equipment, operating at the normal telegraph transmission speeds between 45·5 and 100 bauds, are also shown.

Ferranti (stand 8) have a data link with their exhibits in the adjoining Business Efficiency Exhibition. There, paper tapes are prepared by a document transcriber and fed over telephone lines by a data link (which provides fully checked transmission of digital data) to stand 8 for processing.

On stand 11 is the I.B.M. 1001 data-transmission system which consists of one or more sending stations linked to a central receiving station by telephone lines. The sending station includes a telephone, a terminal containing a card reader and keyboard and a modulating sub-set. The central receiving station consists of a telephone, I.B.M. card punch modified with a data translator and a demodulating subset. Data is read and transmitted at 12-card-columns per second with automatic data checking. The system is shown demonstrating a stock control application.

The 'Collectadata' system of Friden Ltd is exhibited on stand 10. Basically this comprises a transmitter and a receiver. Two types of transmitter are available, one handling punched tape or edge-punched cards, and the other tabulating cards. Any number of transmitters can feed a single receiver, a 'line-busy' indicator which holds transmission until the line is clear arranging the flow of data from each transmitter in turn. A feature is that eighteen digits of variable data can be set up on dials, eight digits being read out when transmission commences, and the remaining ten when a transfer code is read. A parity check arrangement checks each code as it is punched.

Plessey (stand 44) have a loop-error detection equipment for use on telegraph networks and similar low-speed data-transmission systems where a return path is available. Outgoing information is stored in shift registers, while information received at the far end is looped back to the transmitting station where it is compared with the corresponding stored data. Any discrepancy causes the system to cease operating and an alarm is sounded.

Stores and memory systems

The Facit Carousel random-access magnetic-tape memory is handled by A.E.I. (stand 15) in the U.K. and is exhibited by that company. A.T.E. (stand 19) are showing magnetic drums and other devices for use in automatic telephone routing, switching and metering.

An I.C.T. subsidiary, Data Recording Instrument Co. (stand 37) specializes in magnetic-tape transports, read and write heads and tape-testing equipment. This concern is demonstrating two digital tape transports under simulated working conditions, although the main exhibit is a tape-testing equipment, and a magnetic drum for the Post Office is also on view.

Claimed to be the world's most advanced computer tape unit, Decca Radar's new type 400 magnetic-tape transport can be seen on stand 17. Decca make many claims for this equipment, not the least of which is that it is highly reliable.

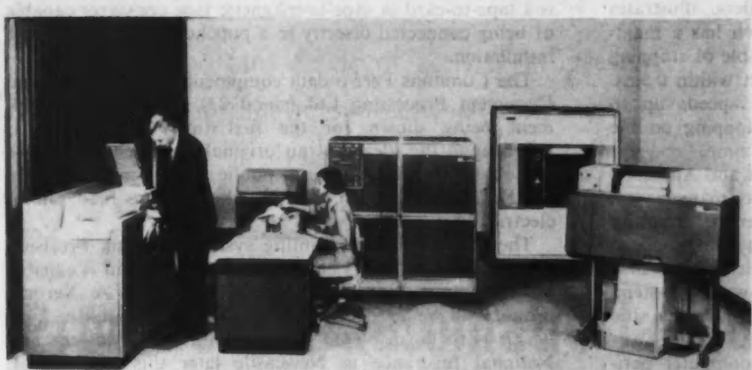
A digital magnetic-tape unit by Magnetic Products Ltd—an associate of Honeywell Controls (stand 7)—is said to be unique in that it is the only unit of its kind which, in one machine, combines a fast stop–start mechanism with a wide variety of input and output speeds. The flux-sensitive

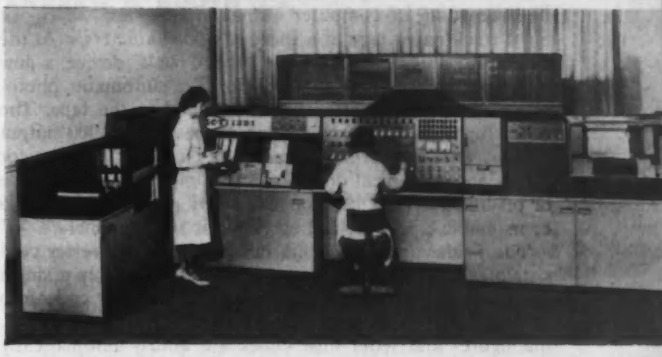
Above: National Cash Register's NCR315 business computer stores data on magnetic cards

Left: Part of English Electric's KDP10 system: left-to-right, monitor printing unit with magnetic-tape units in the background, the control console and paper-tape reader.

Above: The Ferranti Apollo shown here is now installed at Prestwick Airport and being used for experiments into data processing in air traffic control

Left: The KDN2 process-control and general-purpose digital machine shown here at English Electric's Kidsgrove Works, is built up of Datapac units





Above: I.B.M.'s new 1401, intended for the smaller data-processing installation, offers very high punched-card speeds
Top right: The latest Stantec computing system is installed at Cardiff University
Bottom right: The new I.C.T. 1301 operates with punched-card and/or magnetic-tape input and output as well as printed output at at 600 line/min

read head can check characters while it is stationary, and the close spacing of the read and write heads allows a character to be checked before the next one is written. If checking indicates that a character is incorrect then, since this character is held in the input memory, it can be rewritten one bit later.

M.S.S. Recording Co. (stand 33) are showing flux-sensitive heads for reading magnetic tape at very low speeds.

Mullard's Component Division (stand 47) offer a complete service to the computer industry in the field of magnetic-core storage, and are showing examples of complete storage units, stacks, and square-loop cores.

Transistor-circuit ferrite-core memory systems, a new large-capacity magnetic store, and a new fast start–stop computer-tape unit are among the exhibits of Plessey's Electronic and Equipment Group (stand 44). A fast low-capacity store uses tunnel diodes as storage elements and is constructed in self-contained modules having a basic printed board containing 16 bits/word, this arrangement providing flexibility for designers of logic systems. Still under development is a 400,000,000-bit random-access store in which magnetic-oxide-coated disks are the storage medium; access time is 200ms. Also shown by Plessey is a 1024-word 50-bit memory system for the Ferranti Atlas; cycle time is $2\mu s$ and access time $0{\cdot}7\mu s$ approximately. Plessey's Components Group are showing a matrix tester, a patterned inhibit matrix, a decoding matrix, a microstack, cores and multi-aperture devices.

Three new magnetic-storage drums—types C, D and E—are shown by Sperry Gyroscope on stand 39. The earlier types A and B are already in use by the Post Office. Sperry claim an unusually low cost per bit and long-term reliability. A feature of the types C and E drums (the latter a low-speed 16in diameter drum) is that slave units can be added to multiply the capacity up to four times, if need be. The type D drum, a high-speed small-capacity unit, is only 3in in diameter, and is available in 6000, 8000 and 12,000 rev/min versions.

Peripheral equipment

There is, of course, a great deal of peripheral equipment on show, the difficulty being to define the term 'peripheral', particularly as several of the data processing systems mentioned under the heading 'digital computers', above, seem to consist in the main of a great deal of peripheral equipment bound together for a common purpose.

Accoünt-Tokens Ltd (stand 53) are showing their new 'Printapunch' which uses code holes in embossed plastics or metal plates to punch significant data into pre-scored tabulating cards using standard punching code. Simultaneously the machine will punch constant and variable data into the cards, and imprint legible information from the embossed plates.

Addo Ltd (stand 4) are showing a range of peripheral equipment. A shuttle-carriage machine is linked to a tape punch to produce input tape for a computer operation. They also have a book-keeping machine linked to a card punch to produce tabulating cards, and another book-keeper linked to an I.B.M. card punch in order to demonstrate how tabulating cards may be used for ledger posting. Addo also demonstrate a simple data-collection system for control of stores, data logging, and strip printing.

A.E.I. (stand 15) are showing the Swedish Facit high-speed tape punch and high-speed tape reader.

Associated Automation (an Elliott-Automation company—stand 52) are exhibiting the Elliott high-speed card reader. Two developments of the standard card reader are being demonstrated. One is the automatic strobing card-reader which eliminates the necessity for special cards and can be specified for 65, 80 and 90-column cards. The stepping card-reader has been designed for coupling to add/listing machines, typewriters and accounting machines and can also be used for machine tool control. The demonstration shows it operating an Addo-X add/listing machine with a three-shuttle carriage and duplex registers.

An interesting demonstration of Associated Automation's high-speed and low-speed paper-tape readers, illustrates their stopping power. The high-speed version has a maximum speed of 1000 characters/s and is capable of stopping on the character actually being read, in fact within 0·5ms. The low-speed version which operates at speeds up to 200 characters/s, and is also capable of stopping on the character being read, is shown for the first time.

The Bandatronic machine shown by Block and Anderson on stand 6, can calculate in sterling for as many as six input/output typewriters each on a different program. Punched-paper tape for computer input may be produced as a by-product of typing. Block and Anderson are also showing their Typetronic 2215, a document-writing system. Activated by edge-punched cards or punched tape the machine will type at over 100 words/min.

On the Creed stand (26) is a range of computer peripheral equipment, including two high-speed output machines both of which are claimed to be the fastest of their kind. The Model 3000 tape punch is designed for the direct on-line recording of computer output in five-, six-, seven- or eight-track paper tape at a speed of 300 characters/s. At the exhibition, this features a code 'check-back' device, a new optional facility that provides for the automatic photo-electric inspection of the codes punched in the tape. The other high-speed Creed machine is the model 1000 output printer. This is a serial (character-by-character) printer, for use as an economical direct-on-line computer-output device or off-line playback unit, controlled by punched-paper tape or magnetic tape. Speed of operation is 100 characters/s.

The Friden (stand 10) punched-tape code converter consists of a paper-tape reader and a punch housed in a single unit, and is capable of converting any normal code into any other normal code. When converting to five-track code, the figure- and letter-shift codes are added automatically to the output tape.

Jenkins Fidgeon (stand 45) are emphasizing their new range of punched-card and ancilliary equipment. This includes equipment used in conjunction with the I.B.M. 3000 series punched-card system, and equipment for storing, transporting, sorting and handling punched cards.

An important feature of the new Leo III computer (stand 43) is the high-speed Anelex printer which will be demonstrated. Visitors to the Leo stand can also see a magnetic-tape transport and a paper-tape reader linked to an input assembler working at 1000 characters/s.

An integrated d.p. system by Olivetti (stand 22) includes peripheral machines from their range of Audit Telebanda accounting and typewriting equipment, with built-in tape punches which produce six-channel punched-paper tape as a by-product of raising the prime document; at the centre is a tape-to-card or tape-to-magnetic tape converter capable of being connected directly to a punched-card or computer installation.

The Cummins Perf-o-data equipment shown by Original Document Processing Ltd (stand 23) is American equipment being shown for the first time. This range is based upon the idea that an original document should be readable by both the general public and by a machine. In the Perf-o-data system, perforated digits are read photo-electrically.

The Xeronic output-printing system of Rank Precision Industries (stand 24) is based on xerography and is capable of an output speed of 4700 charecters/s. A Xeronic printer will be used in conjunction with an Emidec 2400 which is to be delivered to the Ministry of Pensions and National Insurance in Newcastle later this year. A.E.I. (stand 15) are demonstrating the Xeronic printer on their stand.

Analogue computers

Among the various analogue machines on show are those of both Electronic Associates (stand 18) and Short Brothers and Harland (stand 16). Short's are showing a quarter-scale model of the 200-amplifier **nuclear reactor simulator** on order by the U.K.A.E.A. Short's **educational analogue computer** which has a component accuracy of 1% and eight amplifiers (up to fifteen amplifiers can be provided) is also on show. A feature of the educational machine is that setting-up a problem automatically provides a visual display of the circuit involved. The Short **Simlac** multi-unit machine is represented by photographs and a display of individual units. This has 112 amplifiers, and a basic component accuracy of 0·01%. Short's are also showing their control system analyser for the rapid investigation of feedback control systems and servo-mechanisms. It can operate at frequencies down to 0·01 c/s and as high as 100 c/s.

The centrepiece of Electronic Associates' stand (18) is the **Pace 231R** high-accuracy machine similar to that recently installed at the Atomic Weapons Research Establishment, Aldermaston. E.A. are also showing the small transistorized **TR-10**, an *x-y* plotter, a data plotter, digital voltmeters, an eight-channel recorder, and examples from their wide range of analogue computing units.

English Electric (stand 9) have displays of various installations of the **Lace** analogue computer.

Benson-Lehner (stand 32) are showing two automatic graph plotters and an Oscar system for transferring data from strip-chart records to punched cards, tape or an electric typewriter.

The Electronic Data Processing Symposium

During the Exhibition a Symposium is being held. This is in six sessions and includes the following papers:

4 October, a.m.; *Progress in the introduction of automatic data processing in government departments* by J. D. Janes (H.M. Treasury), *Production control scheme for Letchworth factory* by J. Grant (I.C.T.), and *Inventory control, accounting and payroll* by A. Bradley (Ford Motor Co.); **p.m.**; *Establishing electronic data processing at the Trygg-Fylgia Insurance Companies—Stockholm* by K-E. Schang (Trygg-Fylgia Insurance Co's Group, Sweden), *Three and a half years practical experience* by N. C. Pollock (Stewarts & Lloyds), *Invoicing* by A. J. Brockbank (Glaxo Laboratories), and *Production control by hiring computer time* by R. B. Baggett (Job White & Sons Ltd).

5 October, a.m. *Provisioning 1300 shops* by D. S. Greensmith (Boots), *Data processing in commerce* by L. G. Bonney (Crosse & Blackwell), *Use of a computer in banking* by J. Letham (Bank of Scotland). *Using a computer for insurance work* by F. C Knight (Commercial Union Assurance Co.); **p.m.**; *An approach to integrated production control* by W. J. Kease A.E.I. Hotpoint), *Commercial planning for an integrated oil company* by W. P. Brown (Shell International Petroleum), *Recording and controlling production stocks* by D. O. Bell Standard-Triumph International), *Finished stock control, production monitoring, sales, statistics, etc.*, by F. Stubbs (A.E.I.), and *Production planning* by J. Antill (Rubery, Owen).

6 October, a.m.; *Survey of the computer bureaux service* by D. W. Hooper (The British Computer Society), *Structural stress calculations* by Dr C. P. Wroth (G. Maunsell & Partners), *Costing oil drilling operations* by G. De Verteuil (Schlumberger Overseas S.A.), *Planned Stock control* by C. H. Bayliss (Ever Ready), *Keeping an inventory of precious metals* by S. A. Emery (Engelhard Industries), *Evaluation of confidential materials* by A. J. Stevenson (Stevenson & Howell), *A market survey* by H. Wormald (Midlands Electricity Board); **p.m.**; *The place of the programmer* by Dr S. Gill (Ferranti), *Character recognition* by Dr M. B. Clowes and J. R. Parks (National Physical Laboratory), *New equipment* by Dr A. S. Douglas (C.E.I.R.).

The important fields of activity at present are in automatic syntactic analysis, and in predictive analysis as a means of accurate translation

PART 1

Progress in automatic language translation

by **ANDREW D. BOOTH** D.Sc.
University of London

THE FIRST INTERNATIONAL CONFERENCE ON THE SUBJECT of machine translation was held at the Massachusetts Institute of Technology in 1952. All of the known experts were present, together with sundry observers, but the whole conference was comfortably housed in a small committee room. The discussions which took place at that meeting are now historical. They resulted in the volume 'Machine Translation of Languages', edited by A. D. Booth and W. N. Locke, and some of the opinions expressed therein have no doubt caused embarrassment to the original speakers many times since the conference ended. A second M.I.T. conference was held two years later, and this was followed in 1959 by a conference held at Western Reserve University, Cleveland, on the subject of standards for a common language in machine translation. The latter conference, too, has been well documented in two volumes which have just appeared. Not unnaturally, so ambitious a scheme as the standardization of techniques within a growing field was doomed to failure. The arguments which took place at this conference, however, are of some permanent value, and, when the time is fitting to consider such standards, may have considerable influence on the discussions.

Last month there was held, at the National Physical Laboratory, the first of these international conferences on machine translation to take place in this country. Over thirty-five papers were read, some by well known pioneers, others by the newcomers who are making such progress at the present time.

HOW IT ALL BEGAN

Before making any attempt to discuss any of the papers in detail, it is worth considering the history of machine translation and the area in which activity appears to be greatest at the present time.

Apart from the early patent proposals of Trojanskij, which were not apparently based on any physical mechanism, the first practical proposals for translation by machine were made by the present author in 1946. At that time they amounted, effectively, only to the use of a computing machine store as an automatic dictionary. Even in this respect the early proposals lacked real practicality. The dictionary proposals would have required storage capacities greater than those even now available, and certainly greater than anything which was envisaged in 1946. These difficulties were not unknown to the research workers, and, in fact in 1947, the first practical proposals in translation were put forward by Booth and Richens, and were tested, both by simulated experiments using human operators performing in the sort of blind way that a computer operates, and by experiments on standard punched-card machinery. In essence, a dictionary was used in these experiments for storing, not whole words, but the decomposition of these words into stems and associated endings. The now well known argument, that from N stems and M endings, $M \times N$ words can be formed, for the storage of only $M + N$ linguistic items, shows how improved thinking could lead to possible means of using the crude and imperfect computers of the early 1950s. The first Booth-Richens proposals intended either to ignore the effect of inflexion altogether, or alternatively to have as the machine output the basic meaning or meanings of words, and some grammatical notes to assist the reader in making sense of the jumble. This tacit assumption that the reader should make sense of the machine translation was in fact the same as the suggestion which Reifler made slightly later, that machine-translated text would need 'post-editing'. Reifler, however, improved on this scheme by suggesting not only a post-editor, but also a pre-editor, who should be an expert in the language from

which translation is to be made, and who should remove ambiguities from the incident text. All of these ideas were well thrashed out at the 1952 conference, and when, at Birkbeck College in 1955, the work was taken up in earnest, under the auspices of the Nuffield Foundation Grant, one of the first things to be done was to modify the original Booth-Richens scheme in such a way that stems and endings in the incident language were transformed into stems and endings in the language translation, so that sensible text was produced on a word-for-word basis, even though, considered in a wider context, much might be desired. At the same time, that is, in 1955–56, the first trials of a new machine-translation program for French to English were made on the Birkbeck computer. This program, quite apart from the fact that it re-united stems and endings in translation, also processed material sentence by sentence, rather than word by word; and furthermore as has been clearly shown by the present author,* the method implied what is now known as 'predictive analysis'. Of this it is sufficient to say that, in operating it, one makes certain assumptions at the very start of a sentence about the way in which the structure of that sentence will proceed. These assumptions are being continually checked as new words become available, so that finally a correct, or as nearly as possible correct, version is produced. In this country at least, progress from this point onwards has been very slow. The reasons for this are twofold. First, and most important, the linguistic data required for writing comprehensive machine programs, even for French to English translation, are almost completely lacking. Second, the machines available in this country have, up to the present, been completely inadequate for any large-scale experiments in machine translation.

To deal with the first point, we may say at once that, upon realizing the defects of classical linguistic knowledge, the efforts of the team at Birkbeck College were immediately directed to methods for the automatic analysis of text, and these investigations have led not only to automatic means of making dictionaries, but also to means of analysing text for stylistic differences. This work was pioneered by L. Brandwood in the mid-1950s, and has since acquired great notoriety, the latest instance being the use of his methods to establish the homogeneity of the existing works of Homer.

In the United States there were some ill-advised experiments, designed more for publicity than for real scientific progress, after which a number of groups settled down to solid work. The pioneers in automatic ditionary-making in the United States were the Harvard Computational Laboratory, where Anthony Oettinger and his team have done sterling work on Russian, which has recently been reported in a large volume. At the Massachusetts Institute of Technology as well, a group under Yngve has produced a number of ideas about the basic structure of all languages. Probably the most promising of these is the idea of 'depth' of language, which may have important repercussions on the future. Starting somewhat later, the National Bureau of Standards, after investigating some of the Georgetown University programs, broke new ground for themselves when Ida Rhodes rediscovered the idea of predictive analysis, which has been briefly explained above. On this side of the Atlantic the idea of predictive analysis perhaps appears to be so self-evidently necessary that it requires no justification. But looking at the contemporary literature in the United States, it certainly appears that, at first at least, there was some difficulty in obtaining acceptance of the virtues of this technique. Other groups of workers in the United States have also been active in the field, and they will be mentioned by name in the detailed report which follows. But suffice it to say that, although sound work is being done by these groups, it does appear at the moment that material of such originality has appeared as to form new pointers to the future.

Russian workers, too, have been most active, the groups in Moscow under Ivanov and in Leningrad under Andreev, to say nothing of the active nucleus of workers in Kiev, have added greatly to the theory of Meta-languages, and it is a great pity that the Russians did not submit papers to the conference. Most of the available reports of Russian work are either out of date or are partial accounts gleaned from second-hand conference reports.

It is perhaps unpopular to urge international co-operation at the present time, but it would certainly be helpful if the Soviets would see that their workers were enabled to attend international conferences, and that such attendance was notified well in advance. It is a source of embarrassment to the organizers of conferences when the Russian delegates arrive unexpectedly two days after the conference has started.

WHAT WAS REPORTED AT THE N.P.L. CONFERENCE

We now come to last month's National Physical Laboratory conference. Thirty-five papers were circulated. These were selected from many more submitted to the International Committee which acted as referee. If it were necessary to say, in a single sentence, the way in which the conference pointed to the future of machine translation, it would be this; that the important fields of activity at the present time are in automatic syntactic analysis and in predictive analysis as a means of accurate translation.

Linguistic relationships

At the conference Paul Garvin (Ramo-Woolridge Corp.) read a paper on the heuristic aspects of automatic linguistic analysis. He examined the relations of language analysis, to such things as the analysis of games. In the latter, with a self-organizing machine, a simple target can be prescribed, namely that the object is to win. This does not occur, however, in language translation, where

* Journ. I.E.E., 3 (1957) 629

the far more nebulous objective is to produce the best possible translation. Garvin's experimental work is as yet in an early stage and does not appear to have been tested on any computing machine. In effect, his earliest experiments will merely compare input text with the dictionary, examine the environments of words in that text, and detect the occurrence of frequent juxtapositions

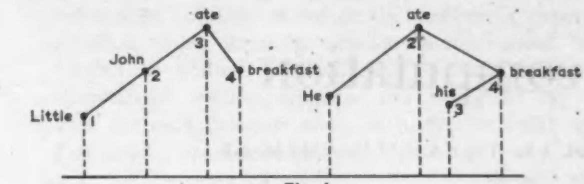


Fig. 1

of different letter or word combinations. This can of course, be quite a useful adjunct to more powerful analyses, but it remains to be shown whether this approach will be a fruitful one.

Warren Plath (Harvard) considered the problem of automatic sentence diagramming. This may appear a novel idea to the uninitiated, but, effectively, the suggestion is that the various words in a sentence can be put into a relation with various forms of tree-like structure, as shown in Fig. 1. The important thing about such tree structures is that they enable one to classify languages, and in particular to decide whether languages are 'projective' or 'non-projective'. It appears, from the work which has been done up to the present, that English, French, German and Russian are projective languages, and this, if it can be established rigorously, is a matter of great importance for machine translators.

These graphical ideas of language structure really stem from the early pioneering work of the Modern Language Research Unit at the University of Cambridge, who were represented by an important paper by A. F. Parker-Rhodes, one of the founders of the group. He suggested a new model of syntactic description, which leads to a satisfactory method of bracketing words in a sentence so as to indicate their functional dependence upon each other. An example of this is the following:

((A (rather lazy)cat)(chases(falling(leaves and butterflies;)))) of course, they(can(easily get away.)))

It is interesting to notice that this bracketing procedure is, in fact, an alternative way of looking at the type of situation described by Plath. A second contribution from the Cambridge group was that by Sparck-Jones, who considered the problems of mechanized semantic classification, and attempted to formulate rules by which text can be automatically used to obtain improved data about classificatory methods.

Dealing with Russian

David Hays (Rand Corp.) spoke on the value of dependency connexions. His paper attempted to show how numerical values could be assigned to syntactic relations in such a way that relations of higher order are established in preference to those having lower values. By higher, in this context, is meant the same sort of thing as is indicated in the diagrams which have just been given. Also from the Rand Corporation was a paper by K. E. Harper on procedures for the determination of distributional classes. It transpired from this paper that the Rand Corporation workers have a corpus of 250,000 Russian words drawn from physics texts upon which they are able to make experiments. The particular experiments described by Harper aim at reducing the structures found in language syntax to terms similar to those which Plath had been discussing. A third paper from the Rand Corporation was that by Dean Worth, who gave transformation criteria for the classification of predicative genitive constructions in Russian. This paper which in a sense expresses everyday linguistics in mathematical logical terms, gives practical transformation rules for the Russian language, when it is considered for automatic translation into English.

Random sentence generating

The contributions from the Massachusetts Institute of Technology came from several departments. Victor Yngve described, in most interesting terms, his experiments on the random generation of English sentences. It may be enquired what use such work is in furthering the aims of machine translation, but a little reflexion will show that, if rules can be formulated which give grammatically correct sentences, these same rules are likely to form at least a part of the corpus required to define the structure of the languages themselves. Yngve formulated a set of 77 rules, which he derived by considering ten sentences in English, the first two of which were:

'Engineer Small has a little train.' 'The engine is black and shiny.'

During the past years, Yngve, realizing the difficulty of transcribing linguistic programs onto machines designed primarily for doing arithmetic, has been responsible for producing a linguistic auto-code called Comit. Using this auto-code and his set of 77 rules, his machine produced large numbers of sentences, which are given as examples in the paper. Some of the more amusing of these are:

'He has four polished sand-domes.' 'Water is big.' 'It's steam is proud of wheels.' 'He is oiled.'

Now all of these sentences are either meaningless or comical, but proper inspection shows that they have the merit of being correctly constructed sentences. It shows also, what is often not realized by the proponents of information theory, that information theory has no connexion with meaning in language, as indeed statistical treatments must inevitably fail to have. This does not imply, however, that the sentences produced by Yngve are useless, because meaning was not the object of the exercise. It would have been quite possible to produce meaningful and not particularly humorous sentences by adding a small sub-unit to Yngve's original program.

To be continued

After burrowing in a mass of mediocrity, one of the British delegates to the third A.I.C.A. conference discovers a few gems and points out current trends.

The state of analogue computation

by **R. J. A. PAUL** B.Sc. (Eng.), A.M.I.E.E., A.M.I.Mech.E.
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THE THIRD CONFERENCE ORGANIZED BY THE ASSOCIATION Internationale pour le Calcul Analogique (A.I.C.A.) was held in Opatija, Yugoslavia, on 9 September 1961. Delegates were informed only in July that the conference location would be changed from Belgrade to this lovely seaside resort on the Adriatic Coast: but the move was welcomed by most delegates—the amenities of the resort compensated for the rather poor technical content of many of the papers.

The original aim of A.I.C.A. was to concern itself with the theory and applications of analogue computation, but this has been extended to hybrid analogue-digital systems and the logical integration of analogue and digital techniques. In this connexion there will be closer collaboration with other international organizations, and in particular with I.F.A.C. and the International Federation for Information Processing. Conferences of the three organizations will be held at three-yearly periods, i.e. one conference each year. The next I.F.A.C. conference will be held in Basle, Switzerland, in 1963, and the next A.I.C.A. conference in London in 1964. It was stated at the general assembly that a joint organizing committee of the three organizations was under review.

A topic of interest raised at the general assembly meeting by Key (United Kingdom) was the question of an international glossary of terms and symbols for computing configurations. Professor Ed. Gerecke (Vice-president of I.F.A.C. and A.I.C.A.) replied that a standards committee was considering this, and a provisional list had been published. The view was expressed that all bodies concerned should get together to produce a truly international list.

Generalities

At the plenary session Professor Ed. Gerecke, representing I.F.A.C., talked about closer collaboration as already mentioned, and R. Tumovic briefly reviewed future trends, stressing the importance of biological applications and a more sophisticated theoretical treatment of analogue methods in general.

At the conclusion of the formal speeches a so-called 'general' debate took place. Six speakers were invited to give short talks on controversial topics, but the time allocated was such that members in the audience had no opportunity to discuss the points raised. Murphy (E.A.L., United Kingdom) discussed various aspects of systems engineering, and Paul (College of Aeronautics, U.K.) talked about integrated digital-analogue systems, automatic programming, and the need for an international language code for analogue and digital systems. The instrumentation of field problem results was the basis of remarks by Redshaw (Birmingham, U.K.). Hermann (Brunswick University) discussed combined analogue-digital techniques and the use of international language codes, while Vichnevetsky (E.A.I., Brussels) stressed the need for better communication between people dealing with new mathematical techniques and those dealing with possible practical applications of these techniques. Finally, Tomovic (Yugoslavia) outlined new applications of high-speed repetitive computers, with specific reference to conformal mapping, integral equations, and statistical studies.

In the subsequent technical sessions there were some ninety papers presented over four days, with two simultaneous sessions each morning and late afternoon. Approximately 250 members attended, from 27 nations.

Highlights against a drab background

As already stated, the general quality of the papers was mediocre, but there were some highlights. The discussion at all the sessions was almost non-existent, and it was an exception rather than the rule for even one question to be asked after the presentation of a paper. This was not due to a complete lack of interest, but rather to the fact that summaries were only available on the opening day. The running of two simultaneous sessions also contributed, as there were many diversions available in the 200-yard walk between the lecture halls. Moreover, although the detailed arrangements of the organizing committee worked smoothly, there was much at fault with the lecture-hall facilities, and the time limit of twenty minutes for each presentation resulted in a rather rapid and sketchy discourse.

These factors prompted me to suggest at the general assembly that preprints of papers should in future be available several months before the opening of the con-

ference and that the selection committee should be more critical in their selection of papers. Professor Hoffman replied that the executive board were considering both these points for the future. If the above suggestions were adopted, papers would have to be written about one year before the conference (as with I.F.A.C.), but the author would bring his paper up to date during his presentation. Further to reduce the number of papers presented, many items of detailed interest could be included as written contributions. It would help if organizations sending delegates did not insist on a paper for each delegate solely to justify his visit: in other words, less tourist papers.

Main technical trends

The main technical trends displayed by the papers appeared to me to fall into the following categories:

1 A deeper theoretical consideration of mathematical programming
2 A mathematical basis for the effect of parameter variations and the use of sensitivity equations.
3 A theoretical basis for the application of computers to statistical problems and the use of high-speed repetitive machines
4 Further progress in hybrid techniques and completely integrated digital-analogue systems for process control and other applications
5 The concept of international problem-oriented language codes for both digital and analogue machines
6 The growing interest in biological applications

In addition, progress is being made in the simulation of large and complex systems such as nuclear reactors, and the interest in field-problem applications was displayed by the fact that three sessions were devoted to this topic, covering some twenty papers.

Progress is also being made in new analogue computing components and circuits. However, apart from the use of transistorized circuits to replace the valve counterparts, it is difficult to foresee significant advances in this context.

A personal choice

It is obviously impossible to give a complete synopsis of the papers of major interest, and the selection below is a personal one.

British contributions included a paper by Professor Redshaw on the use of negative resistance units for the solution of structural problems. This follows the earlier work by Karplus (U.S.A.). Cundall (Ferranti) described the applications of an integrated digital-analogue computer system. The first application was a missile-guidance system, with kinematic problems and axis resolution performed digitally, and missile-control and aerodynamic equations solved in the analogue computer. A digital computer system was the second application, and an important feature claimed was the ability to insert actual components in the control loop. Paul reviewed progress at Cranfield on new hybrid techniques for function generation, and described arrangements for the generation of functions of two or more variables and the instrumentation of correlation functions.

Among the American papers presented I was impressed by Meissinger's. He described an extension of earlier work concerned with the mathematical basis of parameter influence programming, and the establishment of a connexion with selected perturbation techniques commonly used in the analysis of non-linear dynamic systems. Neustadt discussed the applications of linear and non-linear programming techniques. As examples he included the case of simultaneous alegbraic equations, and problems in which it is necessary to maximize continuously a time-varying function subject to certain constraints. Finally he indicated how a repetitive computer, using the techniques outlined, could be used in parameter-optimization problems. Low described an experimental system for generating and measuring the first-passage-time properties of band-pass-limited Gaussian noise, i.e. the statistical distribution of the times that a random variable, y, starting from the value y_0, reaches for the first time a predetermined value $y = y_1$.

Vichnevetsky (Belgium) gave an interesting paper dealing with a spectral method of truncation-error analysis for the finite-difference representation of partial differential equations. The method is based on applying a Fourier transformation to the functions under consideration and evaluating the spectral form of the error on the result of a finite-difference operation.

A paper of wide interest, which provoked discussion, was read by d'Hoop (Euratom, Italy). He described the Apache (*a*nalogue *p*rogramming *a*nd *che*cking) code based on an extension of the I.B.M. Fortran code, to deal with analogue machines as well as digital computers. The particular combination described was the I.B.M. 7090 and the Pace 231R analogue computer with a modified Adios system, which is an automatic system developed by Pace for setting potentiometers and operating problems and operational checks by punched-tape input. d'Hoop explained in some detail the language adopted, and dealt with typical examples in a lecture which overran the allotted twenty minutes by forty minutes without causing instability in the audience.

Hermann (W. Germany) described a related topic on the simulation of analogue computing methods by digital computers using a symbolic input language. The symbolized description of the analogue network produces the corresponding digital program, including digital outputs for all assigned outputs of analogue function units. Therefore the digital program gives accuracy controls for the solutions with the simulated networks. He also indicated how some well known analogue methods lead to interesting digital calculations. Finally he described the simulation of combined analogue-digital systems, in which a program partly in conventional algorithmic language was claimed to have advantages.

Hennig (Norway) described the simulation of human blood circulation. The model simulates the flow dynamics in the circulation with the facility that parameters may be adjusted to give an actual response curve for cardiac output. The effect of manipulations on the model can then be investigated.

The virtual inventor of dynamic programming brings out a classic for control engineers

New guide to adaptive control

by **Prof. J. H. WESTCOTT** B.Sc.(Eng.), Ph.D., M.I.E.E.
Imperial College of Science and Technology

'Adaptive control processes: a guided tour', by Richard Bellman, is an excellent book* and it comes at a very opportune moment. Essentially it is about mathematical method, but it is written in such an evocative style that it makes pleasant reading in spite of the abstract nature of the material and breadth of content. This is something of a literary achievement: an effect which is contributed to by a stylish presentation, including brief quotations from poets and sages at the head of each chapter. The book is aptly dedicated to Lyapunov, Poincaré and Lefschetz, whose works have clearly inspired the author and serve as the foundation on which he has built some modern extensions to the theory and practice of variational methods. But this is an understatement. Variational methods, as the classical European masters left them, were essentially based on the use of calculus. Such limitations as they suffered were due to this, but there seemed to be nothing in practice to be done about it. Dr Bellman suggests that in this day, when computations of a simple kind can be done very rapidly indeed, using digital computers, it is worth while to think again about the limitations of these methods. The difference in viewpoint that this possibility allows amounts to a revolution in mathematical thinking, and it is this fact as much as anything that emerges so clearly from Dr Bellman's carefully composed prose. He says: 'In all cases we face the problems of *feasibility* and *efficient* applications of these general ideas. We try to decompose complicated processes into sequences of simple processes. From this point of view dynamic programming is not so much a fixed set of analytic techniques as a state of mind'.

Not ivory-tower stuff

Dr Bellman has started something. That something is concerned with calculations involving numbers. Perhaps it heralds a new era of engineering mathematics. It is certainly not ivory-tower stuff, but of direct interest in the arena of practical affairs. Those with an engineer's interest in mathematics should read this book—even if the subject of the title does not immediately appeal to them.

But this aspect of the book is more or less a bonus, for the main purpose of the author has been to give an exposition of the power and breadth of application of the technique of 'dynamic programming' (which is the author's shorthand expression for the mathematical theory of multi-stage decision processes, a theory that he has been largely responsible for developing). The first five chapters of the book present us with the essential development of the method, starting from the idea of invariant embedding, which was used to such good effect by Poincaré in the study of non-linear phenomena, by the device of treating the initial condition as a variable and concentrating on families of solutions rather than particular ones. Combining this with a maximizing process and a variational principle, one has the main ingredients. Add in the requirement of developing a solution progressively step by step as a synthetic process, in order that machine solution may be feasible, and you have a method of remarkable power. The author has a delightful way of making even this excursion into mathematical territory not too overpowering. He diverts with verbal asides that give the reader flashes of insight, perhaps when the fog of incomprehension is beginning to descend. For example, he makes this comparison: 'the classical approach to the calculus of variations regards a curve as a locus of points—the dynamic programming approach regards a curve as an envelope of tangents . . . . Thus the classical (variational) approach corresponds to Fermat's principle in optics, and the dynamic programming to Huygen's principle'.

A possible shortcoming of the book is that no examples of application of the method are worked out in detail. Admittedly there are difficulties in doing this, since machine computation is involved. In Chapter 5 the computational process is described in some detail, and this is possibly the hardest part for the novice to follow. In equation 5.10 the notation is even misleading, since the subscripts should more properly descend from *N* rather than ascend from zero, a point of detail that might help some readers. Up to Chapter 9 the treatment is based on the secure foundation of determinism, but at this point we have to take the plunge into the swamps of uncertainty. Says the author, 'It must be admitted that never again will scientific life be as satisfying and serene as in the days when determinism reigned supreme. In partial recompense for the tears we must shed and the toil we must endure is the satisfaction of knowing that we are treating significant problems in a more realistic and productive fashion'. Rather surprisingly, we are eased very gently into this particular swamp, and one senses that from this point onwards the author is leaving the territory in which he is master of all he surveys and taking to that part of the tour which is by courtesy of others. To some extent this has to be true in the sense that to encompass all that is treated in the work is beyond the span of a single man's activities, even a man so prolific as the redoubtable Dr Bellman. However, at the end of each chapter there is an excellent section called 'Bibliography and Comments', giving references to the original work. These sections are very well done. Do not miss the delightful saga by M. G. Kendall (among those for Chapter 9) on how 'Hiawatha designs an experiment'.

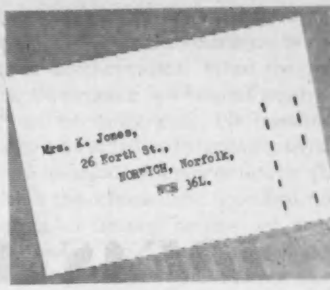
New generation

We proceed from stochastic control processes to stochastic learning models, and thence by theory of games to the even less well secured territory of adaptive control processes. Just before the swamp closes over our heads we are clutching at the straws of aspects of communication theory. The tour is over; our guide is smiling rather mysteriously, but we are certainly not back where we started from. At 42 shillings it is well worth the trip.

This book is almost bound to become a classic. It is the first of a new generation of books on automatic control written with the very particular viewpoint that large-scale digital computers are a fact of scientific life and are here to be used. It is an extremely well written book, constructed with considerable literary competence. As a signpost to the future it will amply repay the undoubted effort required from the reader to stay the course.

* Princeton University Press. London: Oxford University Press 1961. 258 pp. £2 2s. 0d.

There were several items of particular control engineering interest at this year's 'British Ass.' meeting



Talking about automation

by **DENIS TAYLOR** Ph.D., M.I.E.E., F.Inst.P., *Plessey Nucleonics Ltd*

The British Association for the Advancement of Science met at Norwich this year and information was presented of interest to the control engineer.

The President, Sir Gordon Radley,* drew attention to the rapid growth in facilities for communication by trans-oceanic telephone. The transatlantic cable completed in 1956 was the first project of this kind, and was only made possible by the development of underwater electronic repeaters for the amplification of the speech signals at intervals along the cable. A new repeater, capable of amplifying signals in both directions, is to be used for the Commonwealth Pacific project.

Sir Gordon went on to speak about world communications using space satellites. He spoke particularly about employing satellites in circular equatorial orbits at a height of 22,300 miles. At this height the period of rotation is 24 hours, and the satellite appears stationary relative to a point on the earth's surface. Three of these satellites are required to give world-wide coverage for the relaying of radio signals. Sir Gordon spoke also about the problems of aerial design, amplification of the very weak signals from the satellite, and the provision of power supplies for the satellite-borne amplifier.

Also in the Engineering Section program was a paper by Brigadier Holmes, which he called 'Mechanization of the Postal Services'. Roughly 40% of the cost of the postal service is attributable to sorting office costs, so it is here that mechanization is most needed. Until recently, according to Brigadier Holmes, efforts to mechanize postal work have met with little success. However, new machines have been developed which can handle mail automatically, and they are being tried out in sorting offices. In particular, a new coding and automatic sorting technique has promising prospects.

Brigadier Holmes mentioned that, if the co-operation of the public could be relied on, this sorting could be simplified, for letters could be written with addresses *plus* the code word indicating the post-town and the delivery area in that post-town. A postal address with its postal code would appear as in the heading illustration, where 'NOR' represents 'Norwich' and '36L' represents 'North Street delivery area'.

It is necessary to mark each letter so that it can be sorted automatically. This is done by converting the code pattern into machine language—binary code—and stamping this on the envelope. The illustration shows an envelope bearing a typical address and postal code with corresponding phosphorescent spot pattern. The left-hand pattern represents '36L' and the right-hand pattern 'NOR'.

One of the evening discourses was of particular interest to the control engineer. This was entitled 'The Impact of Automation' and was given by Dr B. V. Bowden, Principal of the Manchester College of Science and Technology. Dr Bowden mentioned that the Senate of the United States had held a series of meetings on this subject some three or four years ago, and the results of their deliberations are now available in several large volumes of printed matter. From a perusal of this work Dr Bowden had formed the impression that the learned committee had found considerable difficulty in defining 'automation', and had not come to any firm conclusions as to its impact. For these reasons, Dr Bowden said, he introduced the subject with some trepidation. However, his lecture was a tremendous success. He spoke of the industrial revolution, and the building-up of the Lancashire cotton industry, drawing the conclusion that the introduction of automation always has both good and bad results. He then went on to consider automation in our time. What are the differences? Are we to be at the receiving end this time, or will we be able to repeat the Lancashire textile story over again? Dr Bowden then tried to put forward the necessary criteria for the latter, emphasizing the enormous build-up in science and technology, and the important place of the scientist and engineer in our modern world.

Dr Bowden gave many statistics on the growth of rate of production with the introduction of mechanization and automation in the engineering and chemical industries, and went on to discuss electronic computers and how they were helping—and could further help—our economy. He spoke about design calculations for large engineering undertakings, accounts, stores and payrolls for large organizations, as well as more trivial but interesting applications such as playing chess. He gave it as a considered view that present organization was leading to larger and larger numbers of clerks, and that the most important job for the computer in the future would be to carry a large share of the routine computation and logging of data.

* Sir Gordon Radley is one of *Control's* 'Viewpointers' this month—see p 85 —EDITOR

A monthly review — under basic headings — of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are interested in instrument and control systems

IDEAS APPLIED . . .

. . . to TEMPERATURE

Rapid compensation for changes of mains voltage in a furnace controller

by J. W. DALTON, Electrical Research Association

For a furnace that is required to maintain the temperature within close limits, the value of the heating current should be independent of random voltage fluctuations. Where there are a number of furnaces, as in a creep testing laboratory, a mains voltage regulator has the disadvantage that, should it operate incorrectly, the temperatures of all the furnaces will be affected, and a better alternative is to incorporate a constant-current regulating feature

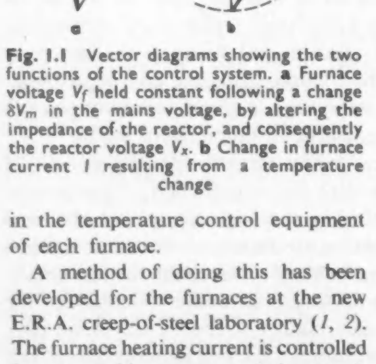


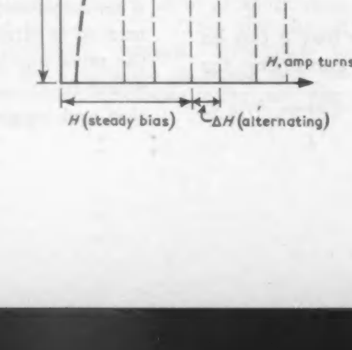
Fig. 1.1 Vector diagrams showing the two functions of the control system. **a** Furnace voltage V_f held constant following a change δV_m in the mains voltage, by altering the impedance of the reactor, and consequently the reactor voltage V_x. **b** Change in furnace current I resulting from a temperature change

in the temperature control equipment of each furnace.

A method of doing this has been developed for the furnaces at the new E.R.A. creep-of-steel laboratory (*1*, *2*). The furnace heating current is controlled by a saturable reactor, and the associated electrical equipment is made to do the double duty of **(a)** rapidly compensating for changes of mains voltage by altering the reactance of the reactor in a manner that keeps the furnace heating current constant, and therefore the power constant, and **(b)** correcting any temperature deviations by altering the value of the heating current, thereby altering the power. Since temperature deviations under the latter conditions are slow, their correction does not conflict with mains voltage change compensation. Fig. 1.1a is the vector diagram for duty **(a)**, and Fig 1.1b for duty **(b)**.

The resistance thermometer and saturable reactor method of temperature control comprises an electrical resistance bridge network which has one of its arms in the furnace and, owing to the temperature-resistance characteristic of this arm, the output voltage of the bridge is a function of the furnace temperature. The saturable reactor consists of a three-limb core of silicon iron laminations. The windings on the outer limbs carry the a.c. furnace heating current, and a winding on the centre limb carries a d.c. current generated in the control equipment. The magnetic flux in the two outer limbs is biased by a steady flux from the centre limb. As shown by the graph, Fig. 1.2, the alternating flux generated by the furnace

Fig. 1.2 Saturable reactor core magnetization curve

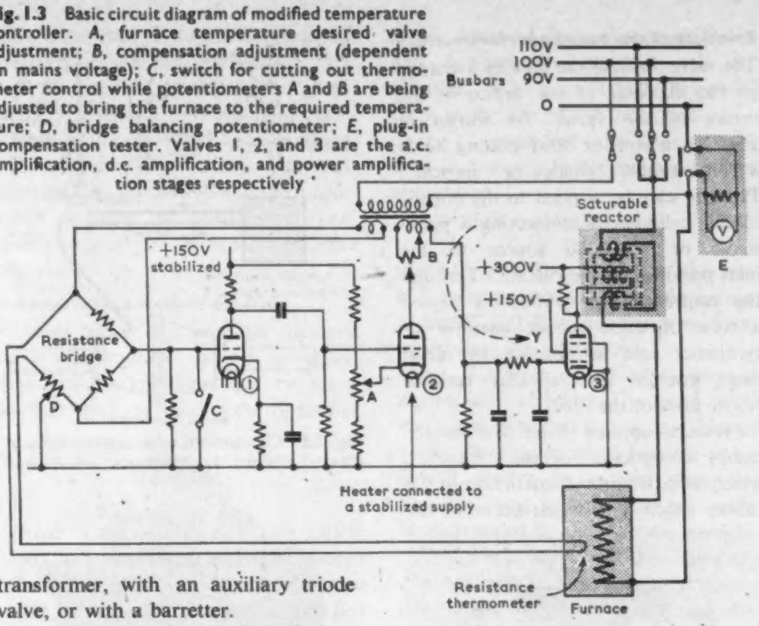


heating current follows a small hysteresis loop. The reactance offered to the furnace current will be proportional to the amplitude of this loop along the B axis. It can seen be that this depends on the amount of steady bias flux, and is small for a large bias and large for a small bias.

Fig. 1.3 shows the basic circuit of the equipment employed to keep a constant temperature. The bridge is energized by 4V a.c. and its output is amplified in valve 1 of the controller. One half of each wave is suppressed in valve 2, by supplying its anode with a.c. derived from the mains, thus making it a phase-sensitive rectifier. The resultant intermittent d.c. signal is smoothed and further amplified in power valve 3, which supplies the d.c. current for magnetically biasing the core of the reactor. The amplifier, which is basically an instrument made by C.N.S. Instruments Ltd, and the reactor used for creep furnace control, are shown in Fig. 1.4.

As there are two stages of d.c. amplification, i.e. valves 2 and 3, and valve 2 receives its anode and heater voltages from the mains as shown in Fig. 1.3, its mutual conductance will vary with mains voltage in the direction to cause the anode current of the power valve to increase with a decrease of mains voltage, and *vice versa*. When this effect, which is due to circuit coupling Y in Fig. 1.3, was investigated, it was found that a ratio of furnace voltage to mains voltage could be chosen, such that a change in mains voltage caused the reactor reactance to change just the amount needed to keep the furnace current unchanged. It was found desirable to stabilize the heater voltage of valve 2; there are several ways in which this can be done, e.g. with a constant current heater

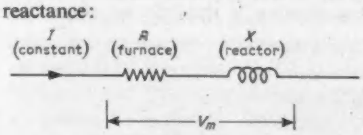
Fig. 1.3 Basic circuit diagram of modified temperature controller. *A*, furnace temperature desired valve adjustment; *B*, compensation adjustment (dependent on mains voltage); *C*, switch for cutting out thermometer control while potentiometers *A* and *B* are being adjusted to bring the furnace to the required temperature; *D*, bridge balancing potentiometer; *E*, plug-in compensation tester. Valves 1, 2, and 3 are the a.c. amplification, d.c. amplification, and power amplification stages respectively



transformer, with an auxiliary triode valve, or with a barretter.

A scheme based on this behaviour of the amplifier has been devised which permits correct compensation to be obtained by selecting a suitable supply voltage from busbars, and effecting residual compensation by adjusting the mutual conductance of valve 2. This is achieved by making the appropriate adjustments of the stabilized d.c. bias voltage applied to the cathode, and of the a.c. voltage applied to the anode. These adjustments are effected by controls *A* and *B* respectively (Fig. 1.3).

The relationship between the change of mains voltage and change of reactance needed to keep the current constant would conform to the following equation if the reactor were a pure reactance:



$$V_m = I\sqrt{(R^2 + X^2)}$$

Fig. 1.4 Amplifier and reactor used for creep furnace control system

Whence

$$\frac{dV_m}{dX} = \frac{V_m X}{R^2 + X^2}$$

$$\therefore \quad \delta X = \frac{\delta V_m}{V_m} \cdot \frac{(R^2 + X^2)}{X}$$

Where I = furnace heating current, R = resistance of furnace plus resistance of reactor a.c. windings, X = reactance of reactor, V_m = mains voltage, δV_m = small change of mains voltage, and δX = corresponding small change of reactance.

The compensation is checked by temporarily inserting a resistance in series with the supply to the furnace plus the supply to the amplifier, to lower the voltage a small amount, thus simulating the effect of a drop in the mains voltage. When potentiometers *A* and *B* are correctly set, the furnace voltage will remain unchanged during this operation.

An advantage of this scheme is that the furnace can be brought directly to any desired temperature by leaving it alone with the correct furnace heating current and with the resistance bridge output short-circuited. When the furnace temperature has become steady at the desired temperature, the resistance bridge is switched in by opening switch *C* and balanced with potentiometer *D*.

With the scheme here described, the changes of heating current are small and never rapid, and temperature fluctuations can be reduced to not more than ½ degC at 600°C. Also, this makes it possible to employ a contact ammeter to provide stand-by protection against accidental over temperature.

Acknowledgement
The author wishes to thank the Director of the Electrical Research Association for permission to publish the above description.

References
1. Dalton, J. W.: 'Equipment of the New Creep of Steel Laboratory', *Co-operative Electrical Research*, 1961 (*14*, July), pp. 15–19.
2. *Control*, 1961, *4* (*38*, Aug.), pp. 100–101

IDEAS APPLIED . . . *. . . to DENSITY*

Null balance instrument for accurate determination of gas density

by J. MARTIN, Distillers Company Ltd

A new instrument for measuring the true density of gases by their effect on the buoyancy of an evacuated quartz sphere, has been developed by the Instrumentation Section of The Distillers Company Ltd. It may be used for gas chromatographic analysis or for the continuous measurement or control of gas streams. The measuring

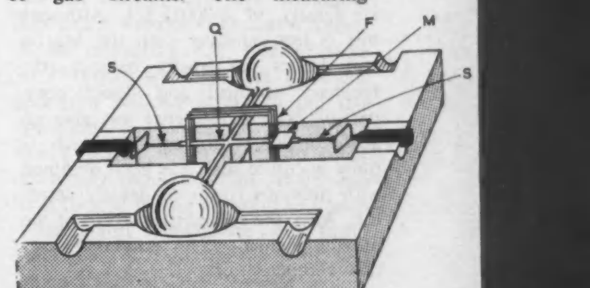


Fig. 2.1 Detector assembly shown mounted in lower half of cell body

element is of the null balance type using electromagnetic feedback, and because of this it is particularly insensitive to vibration and shock.

In principle the detector consists of two identical spheres joined by a rigid rod. This sphere assembly is allowed to pivot about the horizontal axis on a metallic suspension strip, which also acts as the leads for the feedback coil. A small mirror is also mounted on the suspension. The test gas is passed around one buoyancy sphere and a standard gas is passed around

the other sphere. Any difference in the density of the two gases tends to pivot the assembly. This tendency is detected by a light beam and photocell system which sends a current to the feedback coil. This reacts with an external magnetic field maintaining the assembly in a null position. The feedback current is proportional to the difference in densities of the gases.

Well proven micro-assembly techniques have been used in the construction of the suspended assembly (Fig. 2.1). At right angles to the sphere assembly is a further short quartz rod Q which supports the multi-turn feedback coil F and to which is attached the suspension strip S. A 2 mm square mirror M is mounted horizontally on the suspension. The spheres move in chambers which are kept small, to give fast sweep-out, and are connected to the gas stream by channels designed to minimize the effect of flow or turbulence. The rod moves in narrow slots connected to a central chamber which houses the feedback coil, mirror, and suspension, and which is vented to prevent mixing of the gases in the sphere chambers. The cell may be temperature and pressure controlled. A simple d.c. photocell amplifier provides the feedback, with provision for operating a potentiometer recorder.

The apparatus will detect changes in density of 0·00055 g/l. Although this is less sensitive than the Martin and James gas-density balance, the feedback method and direct comparison with a reference gas give an absolute linear indication, which is more accurate than has been obtained with previous forms of density detector. Also, the symmetrical form of the moving element gives good temperature compensation.

. . . to FLOW

Control valve for slurries

by F. T. C. DOUGHTY, Neldco Processes Ltd

The recent increase in the use of slurries as a means of handling solids has accentuated the need for valves which will control this type of material satisfactorily. A design which has proved suitable for these applications is the 'round aperture' valve, which is now available in this country under the name of 'Sala type C'. This valve may be operated manually, or incorporated in an automatic control system.

Principle of the round aperture valve

The valve throttles the flow by a change in the diameter of the orifice in the centre of the valve. As shown in Fig. 3.1, a steel or alloy casting holds a thick rubber cylinder or 'muscle'. Pressure can be applied to the outside of this cylinder by connecting a pneumatic or hydraulic source to the inlet provided in the casting. Through the centre of the cylinder is passed a tube of thick rubber (natural or synthetic) held in position by metal rings inserted into annular recesses in the ends of the tube.

Pressure applied from the source causes constriction of the 'muscle', which in turn causes constriction in the rubber tube. The construction of the latter allows for a gradual reduction of internal diameter, directly proportional to the pressure. An external pressure gauge gives an accurate indication of the diameter of the aperture; under constant head conditions the pressure gauge is therefore acting as a flowmeter.

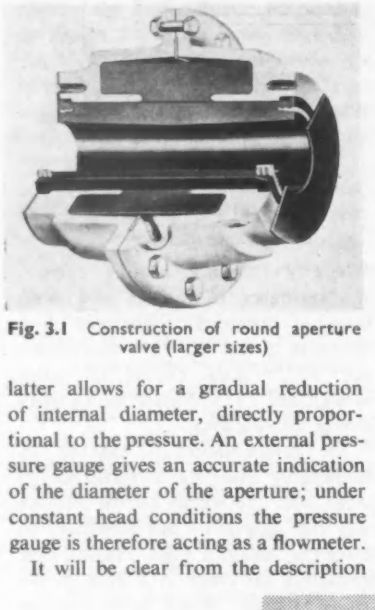


Fig. 3.1 Construction of round aperture valve (larger sizes)

It will be clear from the description above that this valve, when partly closed, resembles a Venturi and consequently the pressure loss is low. It will also be seen that the rubber tube is the only part of the valve in contact with the liquid, and that it offers no obstructions to the flow.

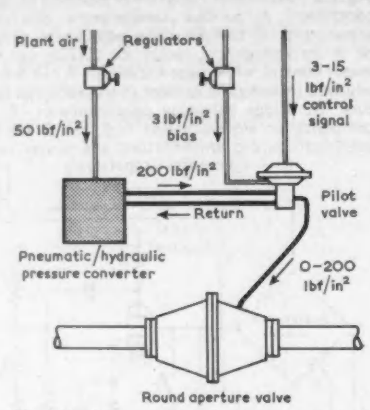


Fig. 3.2 Components of automatic control scheme, where high-pressure air is not available

The orifice remains perfectly round down to about 50% of the nominal diameter, but below this point irregularities may occur owing to the natural characteristics of rubber when under compression. It is therefore desirable to install a size of valve that will normally operate between full bore and 50% bore. It is not advisable to use this type of valve for permanent closure, though it can be closed for short periods. If a permanent shut-off is necessary, it is advisable to install a normal type of plug or gate valve.

A pressure of 200 lbf/in² above the line pressure is required to close the

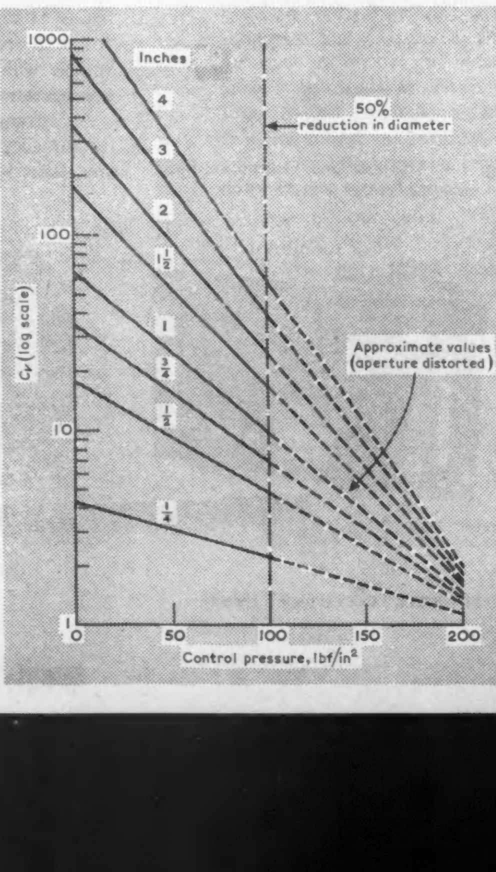


Fig. 3.3 C_v plotted against control pressure for valve sizes from ¼in. to 4in. Values are only approximate when valve throat is less then 50% of its full size, because of distortion of the rubber

valve completely, but normal operating pressures are substantially less.

If the method of calculation given below is followed, the maximum operating pressure can easily be determined and the pressure source provided accordingly. Either hydraulic or pneumatic pressure is satisfactory, and several valves can be operated from one source.

Automatic and remote control

If plant air at the required pressure is available there is no problem. Standard air amplifiers can be fitted to each valve, permitting the operating

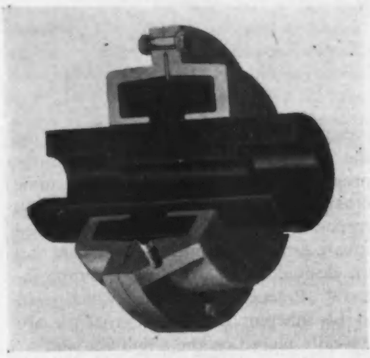


Fig. 3.4 Construction of the smaller sizes of valve

pressure to be controlled directly by 3–15 lbf/in² instrument air signals.

If air pressure is not available, it is probably more economical to install a hydraulic system, unless a substantial number of valves is to be operated from a single source. Pneumatic–hydraulic converters are available which will produce a hydraulic output at 200 lbf/in² from low-pressure air, and the hydraulic pressure applied to the valve can be controlled by instrument air through a regulator known as the Neldco Pilot. The arrangement using a pneumatic–hydraulic converter is shown in Fig. 3.2. Water is a suitable hydraulic medium, and this type of valve is ideally suited for control from an instrument, as the constant slight flexing of the rubber liner greatly increases its life.

Choice of valve size

A valve of this type should always be smaller than the line and always smaller than any conventional valve. The problem should be approached on the assumption that the valve is a short section of pipe that will pass only the maximum flow required under the normal head conditions. If this is done the valve will always operate with the largest aperture for any required flow, and consequently pressure will be reduced, with considerable improvement in the life of the inner liner.

The C_v method of calculation, widely used in industry, is convenient for this application.

The formula is as follows:

$$C_v = Q\sqrt{(G/P)}$$

where C_v is the flow coefficient, Q is rate of flow in gal/min, G is specific gravity of liquid, and P is differential pressure across the valve in lbf/in².

Fig. 3.3 gives values of C_v plotted against control pressure (applied pressure – line pressure) for various sizes of valve. Bearing in mind that the valve should always be smaller than the line, the most suitable size can easily be ascertained by applying the formula.

Two basic designs of this valve are now available in the U.K., covering the size ranges ¼ in to 1 in and 1 in to 4 in respectively. The larger-size range (Fig. 3.1) has cast-steel bodies and British Standard Table *D* flanges. The design of the smaller models, which have a cast aluminium body, can be seen from Fig. 3.4. The inner liner is extended beyond the casting and recessed so that a standard pipe of the nominal diameter of the valve can be fitted inside the liner, and secured with hose clips.

Controlled-rotor flowmeter

We understand from Gaz de France that the two prototype flowmeters mentioned last month (p. 110) use pneumatic methods for braking the rotor, in place of the eddy-current braking system used on the laboratory model. Pneumatic braking has the advantage that its torque/speed characteristic, for a particular position of the regulating mechanism, is almost identical with that of the rotor operating in the 'maximum efficiency' condition.

Two different systems are under test. In the first, the rotor drives a small centrifugal compressor discharging through a butterfly valve, which is positioned by the regulating mechanism to provide the required resistance. The second method incorporates variable-pitch guide blades in place of the fixed guide blades. Blade pitch is controlled by the movement of the control rotor, so that the power developed by the main rotor is varied. It will be appreciated that the 'maximum efficiency' speed is unchanged, this being a function of the main rotor blade contour and rate of flow only. The regulating mechanism is, in fact, used to adjust the power developed by the rotor at this speed, to make it equal the power absorbed by the bearings and counter mechanism.

. . . to ALARMS

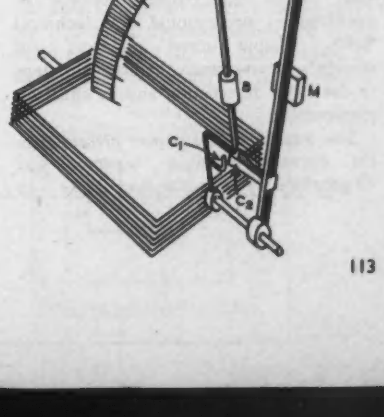
Magnetically assisted meter contacts

The problem of operating contacts on moving coil meters is well known, the power available in the meter movement usually being insufficient to produce adequate pressure for reliable operation. Recently the tendency has been to employ photo-electric methods, or moving vanes interrupting oscillator circuits, in place of directly-operated contacts. The electronic apparatus associated with these methods is often not justified when the contacts are used merely for alarms rather than for two-step control.

The new Weston 'Magtrak' alarm contact system introduced by Daystrom produces high contact pressure by purely electromechanical means. A small permanent magnet *M* (Fig 4.1) attached to the alarm pointer attracts the soft-iron bead *B* on the measuring pointer at the preset alarm point. Contact is made between C_1 and the flexible strip C_2 with a force greater than that provided by the movement alone. Initial contact brings a second 'contact aiding' coil into operation. This coil is wound on the same former as the measuring coil, and provides extra torque, which presses C_2 firmly against a backing strip. During this operation, C_1 moves on C_2 with a wiping action which tends to break down any insulating film which may have formed during a period of disuse.

The alarm contacts are then firmly made until a reset button is pressed, which interrupts the 'contact aiding' circuit. The resulting decrease in torque causes the flexible contact to 'kick' the measuring pointer out of the influence of the magnetic field of *M*.

Fig. 4.1 Magnetically assisted alarm contacts



This month our American correspondents give the first of a number of detailed reports on the more interesting aspects of the recent Joint Automatic Control Conference

Look at America

Second J.A.C. Conference

Recent advances in automatic control were discussed at the Second Joint Automatic Control Conference held at Boulder, Colorado, June 28–30. Sponsorship and support was provided by five major U.S. professional societies: Instrument Society of America, American Society of Mechanical Engineers, American Institute of Chemical Engineers, American Institute of Electrical Engineers, and the Institute of Radio Engineers.

The program included 55 formal papers, two invited presentations, two informal workshops, a special evening address, and a report by the U.S. Automatic Control Team to Japan. The opening session of the conference included the two invited presentations: 'Heuristic Aspects of Adaptive Control', by M. L. Minsky of M.I.T., and 'Modern Research in Automatic Control', by K. Chen of Westinghouse Electric Corporation.

In an evening address, Ewan Clague, Commissioner of Labour Statistics, U.S. Department of Labour, spoke on 'Social and Economic Aspects of Automation.', Clague stressed the urgent need for a healthy, expanding economy that can utilize its labour force efficiently. He pointed out that the changing trends in the labour force present a great challenge to our educational system. The problem we face, he said, is whether or not we can educate a sufficient number of persons to fill the growing number of positions in professional and technical fields. Clague urged engineers and scientists to co-operate in planning steps to deal with automation and its effect on employment.

The quality of the papers presented in the formal technical sessions was unquestionably outstanding. As in the previous J.A.C.C., the theoretical aspects of automatic control dominated the technical discussions. However, unlike last year's meeting which was attended largely by academicians and researchers, this year's 600 registrants included some 270 engineers who could be categorized as directly involved in control applications. This rise of interest by the applications engineers in the often complicated theories of the mathematicians is perhaps typical of trends forced on us by a rapidly advancing technology. J. A. Aseltine of Aerospace Corporation, moderator of a session on adaptive control, made a particularly apropos comment when he said, 'I feel I've solved a lot of problems with my adaptive work, but I'm still looking for someone who needs the solution.'

One of the 55 technical papers has already received a detailed review in 'Look at America'.* Some of the highlights of the remaining papers, as noted by your correspondents, will be briefly discussed in this and future articles.

Optimal control

Of the complete 55-paper J.A.C.C. program, 13 papers were directly concerned with the often-studied optimal control problem. This preponderance of papers in a single area is wholly indicative of a rapidly growing field which has produced well over a hundred technical papers in the past ten years. For the most part, theorists have even begun to agree on what characterizes the optimal control problem. To most theorists and engineers, the optimal feedback control problem implies a determination of the appropriate forcing functions to be applied to a dynamic system subject to certain practical constraints, such that the resultant behaviour of the system is optimal relative to a particular performance index. This performance index may be the time or cost required to force the process from some initial state to some other desired state. Another common performance index is the integrated square error between the actual state and the desired state during a fixed time interval. Practical constraints, which seem to be inherent in optimal systems, are typically placed on the amplitude and/or available energy of the system forcing function. Considerable effort over the past 8–10 years has been directed toward development of mathematical techniques for the solution of optimal control problems. Techniques which have commonly been employed include the calculus of variations, dynamic programming, topology, measure theory, and functional analysis.

The problem most commonly studied in the past has been concerned with time-optimal control, *i.e.*, the problem of minimizing the time required to force the system from some initial state to a desired state, with amplitude restraints. It is generally assumed that the process to be controlled is adequately described by a set of known ordinary differential equations. For example, a particularly interesting and well-known class of problems involves a n-th order linear dynamic system subject to input saturation and governed by the vector differential equation

$$\mathbf{x} = \mathbf{F}\,\mathbf{x} + \mathbf{d}\,u,\ \mathbf{x}(0) = \mathbf{c} \qquad (1)$$

where $\mathbf{F}$ is an arbitrary but constant $n \times n$ matrix, $\mathbf{d}$ is an arbitrary but constant n-vector, $\mathbf{c}$ is an arbitrary but constant n-vector, $\mathbf{x}$ is an n-vector called the state vector, representing the behaviour of the dynamic system, and u is the input control variable and is limited in amplitude by $|u(t)| < 1$ for $t > 0$.

Therefore, the time-optimal control problem involving the dynamic system

* See *Control*, Aug. 1961, p. 97

described by Eq. 1 requires the determination of $|u(t)| < 1$ for $t > 0$ such that $\mathbf{x}(T) = 0$ where T is a minimum; *i.e.*, the system is to be reduced to rest in minimum time.

Y.-C. Ho of Harvard University (*1*) appropriately points out that there are three aspects of interest concerning a time-optimal control problem:

1. Conditions for the existence of a solution: in the solution of the time-optimal problem of Eq. 1, for example, it is known that the matrix **F** and vector **d** must satisfy certain conditions before a solution can be obtained for all **c**.

2. Properties of the solution: assuming that an optimal solution exists for a particular problem, the next step is then the establishment of the various necessary and/or sufficient conditions which the solution must satisfy. Unfortunately, it is at this point that many of the mathematicians leave their eloquent theories for consumption by the engineers.

3. Engineering solution to the problem: assuming that an optimal solution exists, the engineer is faced with the practical problem of obtaining a numerical solution to the problem for any given initial conditions.

Probably the largest amount of literature that has been accumulated on the well-known problem of Eq. 1 has been involved with the third aspect above, *i.e.* the engineering solution to the problem. However, no complete solutions are known to exist up to now. Computation techniques which have been developed are restricted to systems of finite order or to systems with real and distinct roots. In a noteworthy contribution by Y.-C. Ho (*1*), a method of successive approximations is outlined which gives a complete solution to the problem. The convergence of the solution is proved, and it is shown to satisfy all known properties of the problem of Eq. 1.

According to B. Friedland, results which have been obtained using previously developed computational schemes, indicate that there is an underlying canonical structure in all optimum control systems irrespective of the nature of the performance index or of the constraints. In his paper (*2*) Friedland derives this canonical structure by a formal application of the standard techniques of the calculus of variations. It is assumed that the process to be controlled is adequately described by a set of ordinary differential equations as given by the vector form in Eq. 2.

$$\dot{\mathbf{x}} = \mathbf{P}(\mathbf{x}, \mathbf{u}, t) \qquad (2)$$

where $\mathbf{x}$ is a k-vector representing the state of the system, $\mathbf{u}$ is an n-vector representing the control input to the process, and $\mathbf{P}$ is a vector-valued function.

Further it is assumed that there are h

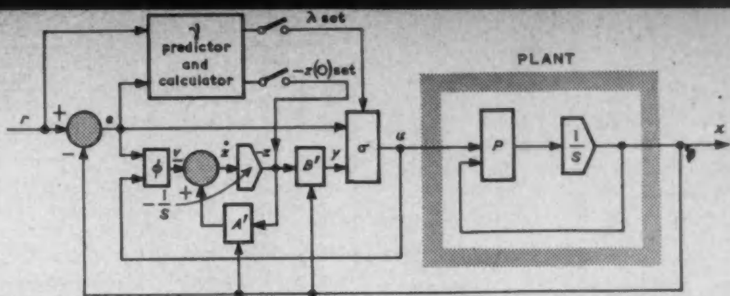
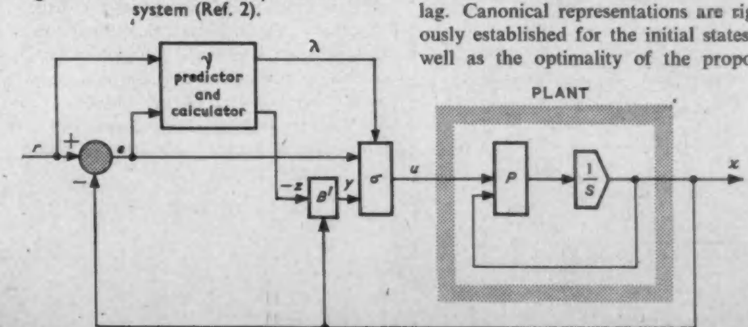


Fig. 1 Conceptual structure of optimal control system (Ref. 2)

constraints which may be expressed as functionals on the input signals and that there is a known trajectory $\mathbf{r}(t)$ which the system is required to follow as closely as possible. The index of performance is correspondingly expressed by a functional on the error $\mathbf{e}(t) = \mathbf{r}(t) - \mathbf{x}(t)$. Determination of the input vector $\mathbf{u}_0(t)$, within the class of allowable inputs which satisfies the constraints and minimizes the performance functional, constitutes the optimal control problem. Application of the calculus of variations results in a set of Euler equations which lead to the conceptual structure of the optimal controller as shown in Fig. 1. The φ-unit depends on the performance functional and the σ-unit depends on the constraints. The γ-unit is a calculator which sets the initial conditions $\mathbf{z}(0)$ of the adjoint differential equations. A shortcoming of a system having the structure of Fig. 1 is that the control input and system output depend upon the accuracy of calculations which determine the initial settings. It is shown, however, that by performing the calculation continuously there is no need for the dynamic portion of the controller. The conceptual structure can therefore be reduced to the equivalent structure of Fig. 2. The underlying result is that the entire controller comprises only instantaneous devices. An example is given in the paper which illustrates the complete design of a time-optimal controller for a plant governed by a first order differential equation, with constraints on amplitude or energy of the actuating signal.

Numerous past investigations have been concerned with aspects (1) and (2) above. In an interesting paper by Markus and Lee (*3*), the problem is considered of the existence of various types of optimal controls for processes which are described by Eq. 2. The performance index is taken to be a generalized 'cost' function. Tests are outlined which enable one to establish the existence of an optimal control in a class of controls

Fig. 2 Actual structure of optimal control system (Ref. 2).



under consideration before proceeding to the construction of an optimal control. It is shown that if the set of allowable controls which does the prescribed task is 'non-empty' then, under rather general conditions, there will exist an optimal control in the allowable set which accomplishes the prescribed task. If the control enters in a non-linear manner, the previous statement also applies, provided that the control functions satisfy a Lishitz condition.

Time-optimal control of on-off sampled-data systems is discussed in two papers, one by Nelson (*4*) and another by Polak (*5*). Nelson considers the class of systems following the familiar state vector description of Eq. 1. The optimal control problem is one of selecting the control input $u(t)$, within the class of prescribed inputs, which takes the process from an arbitrary initial state $\mathbf{x}(0)$, into the origin in the minimum possible time. In other words, this problem is the on-off counterpart to the time optimal problem considered by Y.-C. Ho and others. An additional imposing restriction on the control input in Nelson's problem is the assumption that the state of the system is measurable only at periodic instants of time. Nelson discusses three specific classes of control inputs; namely, saturating amplitude control, simple on-off control, and pulse-width on-off control. It is shown that an on-off controller modified to include pulse-width control has the capability for accurate control as well as the capability for optimal control comparable to that of a saturating amplifier controller. The optimal pulse-width inputs can be specified as a function of the state of the system at each sampling instant. A construction method is presented in the paper which can be used to determine graphically the time-optimal pulse-width control strategy for all second-order plants having real non-positive eigenvalues.

The paper by Polak treats the time-optimal control problem for two specific second-order pulse-width-modulated sampled-data systems, one with a double integrator process and one with a process described by an integral and a simple lag. Canonical representations are rigorously established for the initial states, as well as the optimality of the proposed

law for converting the position of the system in the phase plane into pulse polarity and pulse width. This contribution appears essentially to augment, and be parallel to, the above and earlier work by Nelson (*6*).

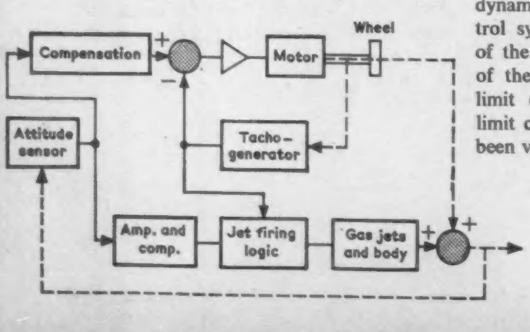
The formulation of the time-optimal control problem involving a randomly changing state in a system in which transitions from one state to another are probabilistic rather than deterministic in nature is carried out by Eaton and Zadeh (*7*). Such systems are referred to as discrete-state probabilistic systems. Specifically the paper is concerned with the determination of an optimal interception strategy for the case where the motion of a target state is governed by a Markoff process, and the transition probabilities of the system are controlled by the input.

Other papers on the subject of optimal control were concerned with time optimal control of non-linear processes (*8*), synthesis and mechanization of quasi-stationary optimal non-linear systems (*9*), optimal control of single input extremum systems (*10*), optimal controllers with 'boundedness' constraints (*11*), design of high-order bang-bang control systems (*12*), a switching criterion for certain time-optimal control systems (*13*), and a minimal time discrete system (*14*).

Attitude control of space vehicles

Two J.A.C.C. sessions concerned with various problems related to aerospace vehicle control were well attended. Special attention was given to attitude control problems. In the opening paper of the first session Mortensen (*15*) discussed design aspects of three-dimensional inertia-wheel systems for attitude control of satellite vehicles. A functional block diagram of one channel of the three-axis attitude control system discussed is shown in Fig. 3. Flywheels are utilized for momentum storage and, in this example, gas jets are utilized for momentum transfer to control the attitude of the satellite. The typical satellite vehicle considered has a circular orbit and a yaw axis coinciding with local vertical. Rotating solar paddles providing an electrical supply are mounted on the vehicle such that the paddle axis is the roll axis. The vehicle yaw and paddle angles are then controlled so that the paddles face the sun. Sizing the system is said to be a major design problem. A significant point made in the paper is that a minimum-weight high-performance system should fire calibrated, timed pulses of gas on wheel speed, rather than switching gas 'on' and 'off' on attitude error signals alone.

Fig. 3 Functional block diagram of single-axis attitude control system (Ref. 15)



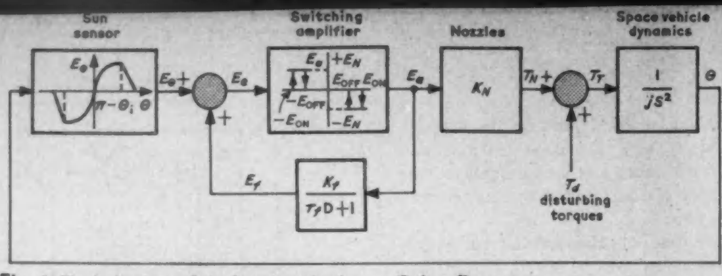


Fig. 4 Block diagram of single-axis attitude control system (Ref. 17)

Gyroscopic coupling produced when reaction wheels or one-gimbal gyros are used to produce the control torques in an attitude control system were discussed in a penetrating paper by Cannon (*16*). The principal disadvantage in a coupled system is that the vehicle wobbles about all three axes, with attendant deterioration in control precision, and the power consumed by the control system is greater by a factor of two or three. In order to improve precision, a special form of control is proposed known as 'decoupling control.' Here the control system keeps track of the spin speed of each of the wheels and computes the torque to apply to each wheel to counter the gyroscopic torques precisely. With a 'decoupling control' computer, dynamic performance and precision are improved, and energy consumption is reduced in certain cases. It is shown that the presumption of a decoupled computer facilitates the accurate evaluation of system performance on the basis of much simpler single-axis relations, even though strong coupling is present. The interested reader should look forward to subsequent papers by the same author which will discuss in detail a comparison of the various methods of control actuation and the performance of orbiting satellite systems.

A gyro-free non-linear attitude control system for a spacecraft was the subject of an analysis by Nicklas and Vivian (*17*). Fig. 4 shows a block diagram of the control system considered Four nozzle-valve cold gas actuators for each axis, mounted in pairs and operated in an on-off manner, produce a torque about the control axis. Both hysteresis and dead zone are included in the on-off controller. Use of 'derived rate' feedback signal (see Fig. 4) is found necessary in order to accommodate the large dynamic range of a typical attitude control system. The results of an analysis of the system, including an investigation of the performance of the system in a limit cycle and the convergence to a limit cycle following a disturbance, have been verified experimentally.

Other Papers

Future reports will be concerned with some of the remaining papers given at this conference. Copies of the *Digest of Technical Papers* may be obtained from headquarters of any of the five sponsoring societies: I.S.A., I.R.E., A.I.E.E., A.S.M.E., A.I.Ch.E. Copies of A.S.M.E., A.I.Ch.E., I.S.A. and A.I.E.E. papers are available from headquarters of these societies. The *Transactions of the I.E.E. Professional Group on Automatic Control* includes all of the J.A.C.C. 1961 I.R.E. papers.

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CONTROL

SURVEY—NUMBER 22

by **R. J. A. PAUL** B.Sc.(Eng.), A.M.I.E.E., A.M.I.Mech.E., *College of Aeronautics, Cranfield*

Introduction

This survey covers computers available in the U.K., the details given for each machine having been supplied by its manufacturer in answer to a set of questions. Two basic types of computer—digital and analogue—form the main subject matter.

Amongst the general purpose machines described, several are particularly suited to process control applications; in particular the Ferranti Argus and the Honeywell H290.

A specialized system designed for process control applications is the Elliott 609, and as such is to be found in the sub-section *Specialized digital/analogue process control computers*. Another interesting machine of Elliott's is the Optimat, an optimizing controller, which is described in the same section.

Analogue process control computers include the Evershed and Vignoles ER92, de Havilland's Anatrol, and specialized units by Miles Electronics and Newman Industries; the latter company also make specialized digital computers to customers' requirements.

Some of the modern American computers, such as the I.B.M. Stretch and 7090, have had to be excluded as they are not yet commercially available over here.

Hybrid analogue/digital computers such as the digital differential analyser (d.d.a.) or incremental computer are discussed under a separate heading. Although there is a considerable development effort being carried out in this country on d.d.a. techniques for military purposes, there do not appear to be many units commercially available in this country.

CHART TERMINOLOGY

Operating time: all times quoted include access time. *Word length:* number of binary digits (bits), or alternatively, number of decimal digits. Parity digits for checking purposes are also given in some cases.

Automatic sequence control: each instruction obeyed in sequence. *Single address:* one instruction, e.g. 'add contents of store 846 to accumulator'.

Multi-address: multiple instruction, e.g. 'multiply contents of store 49 by contents of store 101 and write the result in store 247—two address'.

Modified single address: single address which can be modified automatically during computation, e.g. 'as modified by modifier 3' The symbols (1 + 1) and 1(2) signify respectively 'single address, also specific address of next instruction' and 'single address with two instructions per word'. *Char/s:* characters per second.

Algol: 'Algorithmic programming Language'. Symbolic language for scientific and engineering applications which enables mathematical problems to be programmed without reference to the common code of a computer. Algol has been integrated into courses on numerical analysis and programs can be written by students with very little training.

Expansion of these international languages to deal with index registers, heterogeneous internal memories and magnetic tape units *etc.* is now proceeding.

Alphanumeric: by letters and numbers.

Cobol: 'Common Business Orientated Language' program. Developed in the U.S.A., under the sponsorship of the Department of Defence. Possible international common language program for business and commercial applications.* I.C.T. in this country have adopted this program in the 1301 and have added sterling arithmetic (see table).

The Flexowriter: an automatic typewriter which can read, reproduce, and punch, punched paper tape, and edge-punched or tabulated cards. This reading/punching facility means that it can be used to prepare its own programmed tape for subsequent processing, at the same time as the operator prepares continuous sprocket-punched forms on the typewriter keyboard. It can also be used as an output printer using programmed tape on cards.

Fortran: Formula Translator. An automatic coding system originally designedf or the I.B.M. 704, intended primarily for scientific computation.

Gotran: an interpretive language system that accepts and executes programs written in Gotran language—a subset of Fortran. A Gotran-source program is read into storage, translated into an interpretive language, and immediately executed in the interpretive mode—without the intermediate step of compiling and loading a machine language object program.

Neat: 'National Electronic Autocoding Technique'.

Ramac: 'Random Method of Accounting and Control'.

Report program generator: a means of creating report programs with a minimum of time and effort. Specifications for the report are written by the user in a form which requires no knowledge of machine language coding. The report program generator uses these specifications to assemble a program consisting of all machine instruction necessary for printing the desired report. Report source data may be held in card or tape files.

Spool: Simultaneous Peripheral Operation On-Line. The facility to make maximum use of on-line peripheral units by the operation concurrently of a main program and a priority program which transfers data between peripheral units such as card readers, card punches, tape units, or disk files.

International Multilingual Terminology

It may be of interest to note that the Provisional International Computation Centre in Rome, established by contact between the United Nations, Unesco and the Instituto Nazionale de Alto Matematica (Italy) are producing a multilingual terminology of automatic data processing terms based on the Draft British Standard Glossary of Terms used in Automatic Data Processing.

* (See the Computer Journal Vol. 3, Oct. 1960, page 144.)

ANALOGUE PROCESS CONTROL COMPUTERS

Manufacturer	Description
Associated Electrical Industries Ltd	A.E.I. 1010 *601
Burroughs Adding Machine Ltd	205 general purpose computer *602
	B 5000 *603
	B 251 Visible record computer *604
	220 general purpose computer *605
	E 101/3 Desk computer *606
Electronic Machine Company Ltd	'Storekeeper' Specialized computer *607
Elliott-Automation Ltd	401 *608
	402 *609
	403 *610
	405 *611
	802 *612
	803 *613
	502 *614
	503 *615
E.M.I. Electronics Ltd	Emidec 2400 *616
	SAAB. D21 *617
	Emidec 1100 *618
The English Electric Co. Ltd	Deuce general purpose computer *619
	KDF9 general purpose computer *620
	KDN 2 general purpose

DIGITAL COMPUT

…rer	Description	Clock rate	Number base	Instruction code	Word length (bits)	Arithmetic unit: Type	Arithmetic unit: Floating or fixed point	Arithmetic unit: Add/subtract time	Arithmetic unit: Multiplication/division time	Storage: Quick access store: Type	Quick access store: Capacity	Quick access store: Access time	Main store: Type	Main store: Capacity	Main store: Access time	Backing store: Type	Backing store: Capacity	Backing store: Access time	Library programs: Machine	Library programs: Auto-code
d l.td	A.E.I. 1010 *601	Parallel machine	Binary	Single address	44	Parellel	Both	18 µs	250 µs	Core	4096 words (may be extended)	3·5 µs	As for quick access store	—	—	Magnetic drum type CDM.2; also fast magnetic tape decks	8192 words	20 ms	—	—
s Ltd	205 general purpose computer *602	132 kc/s	Binary coded decimal	Single address sequential	10 plus sign	Parallel serial	Fixed (floating available)	1 ms	9·3 ms	Loops on main drum	80 words	850 µs	Drum	4000 words	8·5 ms	Magnetic tape/Datafile systems	10 tapes/Datafiles (reels–400,000 words each) Datafile (2,000,000 words each)	220 ms/digit effective time	Yes	—
	B 5000 *603	1 Mc/s	Binary or decimal	12-bit address 4 to a word sequential	49	Parallel parallel	Floating and fixed	3 ms	—	Core	4096 words /module (max. 8 modules)	3 µs	Drums 2 off	32,768 words/drum	8·1 µs read–write	Magnetic tape max. 16 units	24 × 10⁶ char/reel	10 ms including start/stop time	Library program will be available	See remarks column
	B 251 Visible record computer *604		Binary coded decimal	Three address	Character orientated	Parallel serial	Fixed	777 µs (average)	58 ms (average)	Core	4800 characters	40 µs	Magnetic stripes on ledger cards	81 char/record; unlimited no. of records	282 ms for ledger-card read operation	As main store	—	—	U.S. banking applications	—
	220 general purpose computer *605	60 kc/s	Binary coded decimal	Single address sequential	10 plus sign	Parallel serial	Fixed	185 µs	2 ms (average)	Core	2000–10,000 words	10 µs	As for quick access store	—	—	Magnetic tape/Datafiles	10 reels: 1,376,000 words each or 10 Datafiles, 4,560,000 words each	46·6 to 114 µs/digit	Yes	Yes
	E 101/3 Desk computer *606	156 kc/s	Decimal	External pin-board, single address sequential	12 plus sign	Serial serial	Fixed	50ms	250 ms (average)	Magnetic drum (3600 rev/min)	220 words	8·3 ms (average)	External paper tape/punched cards	—	—	—	—	—	Yes	Not necessary
Ltd	' Storekeeper ' Specialized computer *607	5 kc/s	Decimal		Variable	Parallel	Fixed	—	—	None	—	—	Magnetic drum	4 drums 700,000 words each	1s	None	—	—	—	—
n	401 *608	333 kc/s	Binary	(1 + 1)	32	Serial	Fixed	204 µs	3366 µs	Delay line	3 words	Immediate (serial)	Magnetic disk	2944 words	6500 µs average	—	—	—	—	—
	402 *609	333 kc/s	Binary	(1 + 1)	32	Serial	Fixed (floating optional)	204 µs	3366 µs	Delay line	16 words	Immediate (serial)	Magnetic drum	4992 words	6500 µs average	Magnetic film	280,000 words/1000 ft reel	—	Yes	No
	403 *610	333 kc/s	Binary	(1) 2	32	Serial	Fixed	153 µs	3366 µs	Delay line	512 words	204 µs average	Magnetic disk	16,384 words	Block transfer	Magnetic tape	—	—	—	—
	405 *611	333 kc/s	Binary	(1) 2	32	Serial	Fixed	153 µs	3366 µs	Delay line	512 words	Immediate (serial)	Magnetic disk	16,384 words	Block transfer	Magnetic film	280,000 words/1000 ft reel	—	Yes	No
	802 *612	167 kc/s	Binary	(1) 2	32	Serial	Fixed	612 µs	21·4 ms	Core	1024 words	Immediate	—	—	—	—	—	—	Yes	No
	803 *613	167 kc/s	Binary	(1) 2	33	Serial	Fixed (floating optional)	576 µs	864 to 12096 µs	Core	8192 words	Immediate	—	—	—	Magnetic film	262,000 words/1000 ft reel	—	Yes	Yes
	502 *614	Asynchronous	Binary	1	20	Parallel	Fixed	2 µs	10 µs	Core	1024 words	0·5 µs	Core	8192 words	3 µs	Magnetic film or tape	—	—	—	—
	503 *615	Asynchronous	Binary	(1) 2	39	Parallel	Both	8 µs	Multiplication 40 to 65 µs; division 100 µs	Core	8192 words	3 µs	Core	Blocks of 16,384 words	3 µs	Magnetic film or tape	—	—	Yes	Yes
s	Emidec 2400 *616	Asynchronous	Binary	Two address	Variable alphanumeric up to 191 characters; fixed for binary (35 + 2 bits)	Parallel	Fixed length with floating-point sub-routines	16 ms	Multiplication 150 ms; division 400 ms	Diode capacitor	64 words	4·5 µs	Core	4096 word modules up to a maximum 32,768 words	12 µs	Magnetic tape (max. 25)	Up to 5·8 million char/2400 ft tape-reel	20,000 char/s	See remarks	—
	SAAB. D21 *617	2·5 Mc/s	Binary	Single address	24	Parallel	Fixed	10 µs	36–44 µs	None	—	—	Core	4096–32,768 words	4·5 µs	None	—	—	Yes	Yes
	Emidec 1100 *618	100 kc/s	Binary	Two address	36	Parallel	Fixed	140 µs	Multiplication 1260 µs; division 1440 µs	None	—	—	Core	1024 words	See remarks	Core Drum (4 off) Tape	3072 words 16,384 words each 4·8 million char/3600 ft reel	— 3 to 26 ms —	Yes	—
h b.	Deuce general purpose computer *619	1 Mc/s	Binary	2 + 1 address	32	Serial	Fixed with floating-point sub-routines	32 µs	2000 µs	Mercury delay-line	402 words (or 626 words, Mk IIA)	From immediate access (4 single-word lines) to 46 µs	Magnetic drum	65,536 binary-coded decimal digits on 16 tracks	15 ms for 32-word transfer; extra 35 ms if head-shift is necessary	Magnetic tape	Up to four twin-transporter-units (Decca)	1·25 ms/word pair (read or write)	Yes	Yes
	KDF9 general purpose computer *620	2 Mc/s	Binary	0 or 1 address (variable length instructions)	48	Parallel	Both	1 µs (fixed point); 7 µs (floating point)	Multiplication 14–19 µs division 30–40 µs	Nesting store Sub-routine jump nesting store; Q stores	16 48-bit words 16 18-bit words 15 special 48-bit registers	Effectively nil 0·5 µs 0·5 µs	Core (cycle time 6 µs)	Up to 32,768 words in increments of 4096 words	6–10 µs reduced to 2–3 µs by use of advance control	Magnetic tape units	9 million alphanumeric char/unit; 16 units may be operated simultaneously	Effectively 240 µs/word; computing may proceed in parallel with transfer	Yes	Yes
	KDN 2 general purpose	140 kc/s	Binary (single- or double-	Single address	18 binary digits rep-	Serial	Fixed (floating-	175 µs or double length	Multiplication 2.75 ms	Single-word registers with	4	—	Core	Expansible in increments of	Cycle time 15 µs	—	—	—	Yes	Alpha code

PUTERS

ibrary programs												
chine	Auto-code	Future development	Input equipment	Output equipment	Valve or transistor	Main applications	Floor area (ft²)	Power con-sumption	First put on market	Number sold	Cost of typical installation	Remarks and special features
	—	Not disclosed	All types of equipment	All types of equipment	Transistor	General data processing	1000	30 kW	—	Not disclosed	Price on application	This computer is a new generation machine capable of simultaneous control of 32 pieces of peripheral equipment
	—	—	Paper-tape reader, 540 char/s; punched card 300/min	Paper-tape punch, 60 char/s; card punch, 100 cards/min; line printer, 1·5 lines/min (120 char/line); supervisory printer	Valve	Commercial data processing	1250	42 kVA	1954	130	£150,000–£250,000	General purpose
ary ram be able	See remarks column	Thin film memory	Card reader (2 off), 200 or 800 cards/min or mag. tape, 50,000 char/s	Line printer (2 off), 650 lines/min; magnetic tape, 500,000 char/s; card punch, 100 cards/min	Transistor	All commercial scientific applica-tions			1961	Recently released	£250,000–£750,000	General purpose information-processing system. All programs compiled automatically by master control program (from Algol/Cobol statements). Equipment problem—language orientated to minimize initial programming. Multi- and simultaneous-processing. Modular construction. No re-programming for change of equipment configuration
ing ca-	—	—	Sorter reader (1 off), 1560 documents/min, 84 char/document; card reader, 100 cards/min; ledger processer, 180/min	Ledger processor line printer, 200 lines/min	Transistor	Bank-ledger posting, finance, hire-purchase accounting	600		1959	100 (approx.)	£100,000	—
	Yes	—	Punched tape (max. 10), 1000 char/s; punched card (max. 7), 100 cards/min; keyboard; magnetic tape	Punched tape, 60 char/s; card punch, 100 cards/min; line printer, 150 lines/min; high speed printer, 1250 lines/min; supervisory printer; magnetic tape	Valve	All commercial data-processing	1500	100 kVA	1958	Over 30	£300,000–£600,000	—
	Not necessary	—	Keyboard; punched tape, (max. 3); 20 char/s punched card (max. 2), 15 cards/min	Sensimatic printer, 108c/min; punched tape 20 char/s	Valve	Scientific and statistical work	144	3·5–5 kW	1955	Over 250 (12 in Europe)	£16,000–£25,000	
	—	Incorporation of sterling facilities	Manual keyboard; typewriter; punched tape; punched card	Illuminated numerals; automatic type-writer; punched tape; punched card	Valve	Stock control, sales analysis, machine loading	18	500 W	June 1960	—	£5000	—
	—	—	Punched tape 40 char/s	Typewriter, 10 char/s	Valve	Scientific	90	5 kVA	1953	1	—	Pilot model
	No	—	Punched tape, 40 char/s or punched cards	Tape punch, 25 char/s	Valve	Scientific	120	7 kVA	1954	10	£30,000	Floating-point model available
	—	—	Punched tape	Tape punch; line printer, 150 lines/min	Valve	Data reduction and analysis	400	25 kVA	1954	1	—	—
	No	—	Punched tape, 180 char/s, or card reader 400 cards/min	Tape punch, 25 char/s, or film, 300 char/s	Valve	Business	500	35 kVA	1956	33	£120,000–£150,000	—
	No	—	Punched tape 160 char/s	Tape punch, 25 char/s	Mixed	Scientific	60	0·5 kVA	1958	7	£16,500–£20,000	—
	Yes	—	Punched tape 500 char/s, or punched cards, 300 cards/min	Tape punch, 100 char/s	Transistor (1500)	Business, scientific, industrial control	195	3·6 kVA	1959	48 (see remarks)	£30,000–£60,000	Sixteen incorporated in Panellit 609 industrial information and computing systems
	—	Yes	Depends on system	Depends on system	Transistor	Real-time data processing	—	—	1960	2	£150,000–£175,000	—
	Yes	Yes	Punched tape, 1000 char/s, or punched cards, 300 cards/min	Tape punch, 100 char/s	Transistor	Business, scientific, industrial control	—	—	1960	0	£60,000	—
rks	—	Faster tape-running and printing speeds being considered	Punched tape, 300–1000 char/s; punched card, 300 cards/min	Tape punch, 30 or 300 char/s; card punch, 100 cards/min; interpreter set, 10 char/s; printer, 600 lines/min	Transistor	Pay rolls, production planning, stock control, statistics, *etc.*	2500	50 kVA upwards	1959	4	Not less than £200,000	Automatic parity-checking program. Input and conversion programs. Test and diagnostic programs: simulator programs: Card-to-tape converter for converting cards to magnetic tape off-line. File-search unit for handling bulk information off-line. Automatic alphanumeric and sterling conversion. Multiplexed keyboard off-line input-unit
	Yes	—	Punched tape, 500 char/s; magnetic tape, 50,000 char/s approx.	Punched tape, 150 char/s; magnetic tape, 50 char/s approx.	Transistor	Data processing, process control	8	300 W	1961	1	—	Small physical unit
	—	Increased magnetic tape speeds			Transistor	As for Emidec 2400	800	15 kVA upwards	1958	15	£125,000–£230,000	Instruction times are inclusive of access time; instructions are obeyed serially. Automatic parity checking. Independent buffering of all units. Off-line working facilities for all peripheral units–maximum of 16 of latter may be linked to one computing centre. Automatic alphanumeric and sterling conversion
	Yes	—	Punched tape 1000 char/s; punched card 200 cards/min; magnetic tape	Punched tape, 30 char/s; card punch 100 chars/min; magnetic tape	Valve	General purpose computer mainly for scientific work (Mk II version for data processing)	—	9 to 13 kW (basic in-stallation)	1955	30	£45,000–£55,000 basic installation	Single-and double-length accumulator provided
	Yes	—	Punched tape, 1000 char/s; punched card, 400 cards/min; magnetic tape	Punched tape, 600 char/min; card punch, 150 cards/min; magnetic tape; printer, 900 lines/min, 120 char/line; Xeronic printer, 3000 lines/min, 120 char/line	Transistor	High speed commercial or scientific data-processing	1400 (basic in-stallation)	10–30 kW (approx.)	1960	2	£120,000 upwards	Logical operations, 2 μs average; shifts up to 4 μs. Double-length arithmetic built-in. Automatic conversion between binary and characters (up to 200 μs). Extremely simple to program
	Alpha code	—	Punched tape, 20 char/s; also switches, keys and counters, and a wide range of other equipment	Punched tape, 20 char/s; typewriter, 10 char/s; provision for analogue–digital, digital–analogue conversion	Transistor	General purpose, industrial process control, and	—	1·6 kW (basic computer)	An-noun-ced	—	—	Small versatile inexpensive machine, particularly suited to data-logging. Off-line and on-line process control. Can act as a slave to KD9 or KD10. Use of Datapac transistorized logical elements.

ANALOGUE PROCESS CONTROL COMPUTERS

Evershed & Vignoles Ltd

*671

Simple computer ER92 (on-line). *Capacity of typical installation*: depends on application—electro-mechanical specialized machine. *Static component accuracy*: 1%.

Operational procedure and method of working: Based on the Evershed electronic repeater principle, it is a computing device for the instantaneous and continuous solution of equations occurring in the day-to-day operation of process control systems *etc.* A pivoted beam carrying coils at each end is subjected to torques developed by the interaction of signal currents, representing the input variables in the coils, with magnetic fields. Displacement of the beam from its balance position results in a change in the grid voltage of a thermionic valve contained in the power unit, and the change in the anode current is fed back to restore the beam balance. The valve also provides the output signal of the computer which is fed to one or more regulating units, controllers, recorder, *etc.*

Measurement, display, and recording: moving-coil meter or potentiometer recorder. *Computing amplifiers*: valve amplifier; input current 0–15mA into 3kΩ. *Passive coefficient networks*: springs, *etc. Function generation*: addition, subtraction, multiplication of two variables, or of a variable by a constant; division of one or two variables by a constant and *vice-versa;* squaring, square-root extraction. *First put on market*: 1956. *Power consumption*: 20W. *Main application*: process control on-line computing.

Remarks and special features: may be completely integrated into a control scheme, evaluating continuously the variables and contents of the controlled process, its output being used to maintain the processing at the desired value.

The de Havilland Aircraft Company Ltd

*672

Anatrol on-line process control computer. *Capacity of typical installation*: equivalent to 75 amplifiers and 25 multipliers over a period of 20s. *Static component accuracy*: 0·1%.

Operational procedure and method of working: time-shared computer, repetitive operation 0·5 to 10s, single-shot operation typically 25s; patching by taper pins and reamed holes; capacitor storage; automatic operational self-check; problem-check as optional extra.

Measurement display and recording: measurement accuracy 0·03%—voltage potentiometer and null detector. *Computing amplifiers:* transistor amplifier; open-loop gain at zero frequency $> 2 \times 10^{6}$; equivalent input noise < 1mV; input-current, 5×10^{-10}A; temperature drift (referred to input) < 2mV/degC; max. output-voltage, ±10V; max. output-current 30mA; max. input capacity, 200pF; max. output-capacity 0·1μF. *Passive coefficient networks*: wire helical potentiometers, resolution 0·05%, set against a standard potential divider. *Function generation*: integration; squaring; square root; logarithmic; exponential; also included, time-division multiplier—0·2% static accuracy. *Price of typical installation*: about £4000 for an average computing unit. *First put on market*: 1961. *Floor area*: 3ft². *Power consumption*: 25W. *Main applications*: process plant control.

Remarks and special features: used for evaluation and study contracts only as yet; modular construction, so expansion limited only by program complexity and/or error accumulation.

Miles Electronics Ltd

*673

Specialized systems to customer's requirements. *Typical installation*: fully automatic control system designed for Atomic Power Constructions Ltd, for the temperature cycling of reactor fuel elements. In this application, an analogue computer compares continuously the actual performance of the specimen with the program information set on to the computer, and the error-signal automatically controls the temperature of the furnace. Two further rigs for similar applications being supplied to the C.E.G.B.

Newman Industries Ltd

*674

Specialized computers for various applications. *Capacity of typical installation*: a typical set of units includes 10 operational amplifiers, function generators, and electronic quarter-squares multipliers.

HYBRID ANALOGUE/DIGITAL COMPUTERS OR DEVICES

Electronic Associates Ltd

*675

Addalink, introduced in 1959 to provide complete coupling between high speed digital computers (Univac 1103A, IBM 704, IBM 709 etc.) and Pace analogue computers.

Idea Mark I introduced in 1960.

Idea Model S, introduced in 1961, is a further development of Electronic Associates' digital expansion system (known as the Advance system) which was first developed for their range of general purpose analogue equipment. Idea Model S is housed in a standard Pace three-bay console with standard Pace 3450-hole detachable patch-panel. It is, however, completely solid-state and the entire equipment is in a temperature-controlled environ. Clock frequency is 250 kc/s to 2·5 Mc/s; Other information is restricted, but available in discussion with the company.

Advance system, introduced late in 1960. The Advance system (*Advanced Digital Versatility for Analogue Computing Equipment*) consists of a computer console with a pre-patch panel system and a selectable and expandable number of hybrid, computer building blocks.

Microstore (digital memory) system, introduced in 1961, provides high-speed point storage and switching facilities on standard Pace analogue computers. Full information available in discussion with the company.

G.E.C. Ltd

*676

Dexan. This is a digital experimental airborne navigator system which is the result of a joint effort by G.E.C. and R.A.E. Farnborough. This equipment is still in the early development stage, and the first application is for navigation. It comprises two calculating sections, a d.d.a. and a general purpose computer). A core matrix store is employed and the unit is fully transistorized. Inputs and outputs are in analogue form.

Rank Cintel Ltd

*677

Corsair. This d.d.a., designed at R.A.E. Farnborough, is now manufactured under licence to the National Research Development Corporation by Rank Cintel Ltd. It is a transistorized machine with patch-board programming which can operate at a computing frequency of 1 c/s with an accuracy of 1%. This accuracy, of course, improves linearly as a frequency is reduced. The operation is sequential, with serial arithmetic and with an iteration rate of 500 steps per second. Word length is 16 digits, including start and sign digits, and the maximum discrimination is 1 part in 2^{15} with a digit rate of 500 kc/s. The storage system is based on ferrite cores, and the number of integrators operated sequentially is 50. Inputs and outputs are whole numbers or incremental. Power consumption is 50W.

SPECIALIZED DIGITAL ANALOGUE PROCESS CONTROL COMPUTERS

Elliott-Automation Ltd

*678

The 609 transistorized industrial computing system. *Clock rate*: 6μs. *Arithmetic units*: serial. *Word length*: 39 binary digits. *Capacity of typical installation*: varies depending on process involved; can deal with transducer signals in the region of 1000 signals at 5 per second. *Types of computing units*: transistor and core transistor logic. *Method of patching*: punched paper tape input, core-store memory in 803 computer, which is central processor of 609. *Analogue-to-digital converters*: resolution, 1 part in 2048; accuracy 0·1%; sample time, less than 5ms. *Digital-to-analogue converters*: shaft-position output to adjust set-point of electric or pneumatic controllers. *Main applications*: process control. *Number sold*: 16.

Remarks and special features: uses Elliott 803 computer as central processor. The 609 system has facilities for time-sharing, and thus running on-line and off-line work virtually simultaneously.

*679

Optimat (an optimizing controller). This is an end-point optimizer; that is, it searches continuously to maximize the ignores mole-hills, *etc.*, and changes direction if necessary, he will arrive at the summit. Design is flexible and based on the

	KDN 2 general purpose computer *621	14(
	KDP 10 data processing system *622	40(
Ferranti Ltd	Pegasus 1 *623	½ N
	Pegasus 2 *624	½ N
	Orion *625	0·5
	Atlas (Muse) *626	—
	Sirius *627	0·5
	Argus process control computer *628	0·5
Honeywell Controls Ltd	H400 *629	—
	H800 *630	—
	H290 process control computer *631	50
I.B.M. (United Kingdom) Ltd	7070 D.P. system *632	—
	7074 D.P. system *633	—
	I.B.M. 1620 *634	20μ cyc
	1410 D.P. system *635	0·7 Ch cyc 4·5
International Computers & Tabulators Ltd	1301 Data processing system *636	1 N
	555 Electronic computer with 240-gang punch *637	15
	Program-controlled computer *638	38
	1201 General purpose computer *639	38·
	1202 General purpose computer *640	38·
Leo Computers Ltd	Leo III digital computer system *641	Asy ous

									jump nesting store; Q stores	words 15 special 48-bit registers	0·5 µs			advance control		units may be operated simultaneously	in parallel with transfer			
KDN 2 general purpose computer *621	140 kc/s	Binary (single- or double-length word working)	Single address	18 binary digits representing one 18-bit fixed-point number or 3 alphanumeric characters	Serial	Fixed (floating-point sub-routines)	175 µs or double length 301 µs	Multiplication 2.75 ms average for 18-bit multiplier; division 5 ms for 18-bit quotient	Single-word registers with full range of arithmetical, logical, and modifying facilities	4	—	Core	Expansible in increments of 512 18-bit words to a max of 4096 words	Cycle time 15 µs	—	—	—	Yes	Alpha code	—
KDP 10 data processing system *622	400 kc/s	Binary	Two address	Variable	Serial-parallel	Fixed	Variable length working: all arithmetic depends on no. of characters in operands	—	Core	Up to 262,144 characters in increments of 16,384 characters	7·5 µs/4 char	See quick access store	—	—	Magnetic tape units	As for KDF 9; 64 units can be incorporated	33,333 or 66,666 char/s (read and write)	Yes	Yes	—
Pegasus 1 *623	⅓ Mc/s	Binary	Modified single address	39	Serial	Fixed	0·3 ms	Multiplication 2 ms; division 5·5 ms	Delay line	55 words (including 7 accumulators)	Immediate	Magnetic drum	9216 words	9 ms (average)	Magnetic tape units	Up to 5 mechanisms	—	Yes	Yes	—
Pegasus 2 *624	⅓ Mc/s	Binary	Modified single address	39	Serial	Fixed	0·3 ms	As above	As above	As above	As above	Delay lines and magnetic drum	128 or 256 words on delay-lines complement to 9216 words on drum	Immediate (for block transfers) on delay lines; 9 ms (average) for drum	As above	As above	—	Yes	Yes	—
Orion *625	0·5 Mc/s	Binary	2 or 3 address	48	Parallel	Fixed	36–68 µs	Multiplication 60–192 µs; division 550 µs	Core	32,768 words (max.)	12 µs cycle time	Magnetic drums	Virtually unlimited	12 ms (average)	As above	16 mechanisms (max.)	—	Yes	Yes	—
Atlas (Muse) *626	—	Binary	Single address (1 or 2 B—modified)	48	Parallel	Floating	1·4 µs (average)	Multiplication 4·6 µs; division 13·6 µs (average values)	Core Fixed store B store Subsidiary store V store	16,384 words 8192 words 128 half-words — —	2 µs cycle time 0·2 µs 0·35 µs 2 µs —	Magnetic drums	24,576 words/drum; 4 drums on first machine	6 ms (average)	As above	Standard provision for 32 mechanisms	—	Yes	Yes	—
Sirius *627	0·5 Mc/s	Decimal	Modified single address	10 decimal digits (each of 4 bits)	Serial	Fixed	240 µs	8 ms (average)	Delay lines	9 words	Immediate	Delay lines	1000 words in basic computer (up to 10,000 max.)	4 ms	—	—	—	Yes	Yes	—
Argus process control computer *628	0·5 Mc/s	Binary	Modified single address	12 bits, with facilities for 24-bit working	Serial	Fixed	20 µs	Multiplication 90 µs; division 180 µs	Core	3072 12-bit words (max.)	Immediate	Inductive peg-board	4096 12-bit words (max.)	Immediate	—	—	—	—	—	—
H400 *629	—	Binary or binary-coded decimal	Three address	48 bits plus 2 bits parity	—	Fixed	120 µs	Multiplication (1560 plus 60 × digits in multiplier) µs; division 5·07 ms (average)	—	—	—	Core	1024 to 4096 words	—	—	—	—	Yes	Yes	—
H800 *630	—	Binary or binary-coded decimal	Three address	48 bits plus 6 bits parity	Parallel or serial parallel	Fixed (floating point optional)	24 µs	Multiplication 162 µs; division 444 µs average	—	—	—	Core	4096 words plus 256 16-bit words of control memory. May be extended to 32,768 words	—	—	—	—	Yes	Yes	—
H290 process control computer *631	50 kc/s	Binary and decimal	Single address (normally one instruction per word); 6-bit operation code; 12-bit address	18 binary digits (17 bits plus sign) or 4 decimal digits	Parallel (word rate 50 kc/s)	Fixed (floating point can be provided)	140 µs	Multiplication 0·8 ms; division 1·4 ms	Core	1024, 2048, or 4096 words	20 µs	Magnetic drum	4096 or 8192 words	17 ms for first word 0·14 ms/word thereafter	—	—	—	Programming aids available	—	—
7070 D.P. system *632	—	Decimal	Sequential, one address	10 digits and sign	Serial-parallel	Fixed (floating point optional)	36–76 µs	Multiplication 232 µs to 1620 µs; division 672 µs to 4992 µs	—	—	—	Core	5000 or 10,000 words	6 µs to access whole word	Ramac disk	Maximum 48 × 10⁶ decimal digits	500 ms (average)	Yes	Yes	—
7074 D.P. system *633	—	Decimal	Sequential, one address	10 digits and sign	Parallel	Fixed (floating point optional)	10 µs	Multiplication 28–86 µs; division 46–106 µs	—	—	—	Core	5000 or 10,000 words	4 µs to access whole word	Ramac disk as for 7070 DP	—	—	See remarks	Yes	—
I.B.M. 1620 *634	20µs basis cycle	Decimal	Two address add to storage	Variable	Serial-parallel	Fixed, with floating-point sub-routines	560 µs for 5-digit fields	Multiplication 4·96 µs for 5-digit fields	—	—	—	Core	20,000 decimal digits	Cycle time 20 µs	—	—	—	Yes	Yes	—
1410 D.P. system *635	0·75µs; Character cycle-time 4·5µs	Alphanumeric binary coded decimal; arithmetic logic quibinary	Comprehensive (about 330 instructions)	Variable: 1–100,000 characters	Parallel by bit, serial by character add storage to storage	Fixed	About 100 µs for 6 digits plus 3 digits	Variable: 6 digits by 4 digits about 1 ms	Core	Variable from 10,000 to 100,000 characters	4·5 µs	See quick-access store	—	—	Magnetic tape Magnetic disks (Ramac)	Up to 20 tape-units of several types Up to 5 Ramac units (100 × 10⁶ characters)	Maximum character rate 62,000 char/s Average 600 ms, minimum 90 ms	Fortran, Cobol, Report generator, Spool	Yes (see previous column)	No public announcem[ent]
1301 Data processing system *636	1 Mc/s	Biniten	One address	12	Serial-parallel	Fixed (sub-routines floating point)	21 µs	Multiplication 175 µs/digit; division 220 µs/digit	Core	400 to 2000 words	6 µs	Magnetic drum	12,000 to 96,000 words	6 ms (average) 11·4 ms (max.)	Magnetic tape	Up to 8 units	Automatic interrupt facility	Wide selection	Cobol	—
555 Electronic computer with 240-gang punch *637	15 kc/s	Biniten	Multiple address	10	Serial-parallel	Variable fixed	10 ms average	Multiplication 18 ms (average); division 40 ms (average)	3 valve registers	3 words	1 ms	Regenerative type drum	1050 numeric digits	10 ms (average)	Cards	—	—	Tax and alpha conversion	—	—
Program-controlled computer *638	38 kc/s	Biniten	One address	16	Serial-parallel	Fixed	0·5 ms	8·5 ms (min.)	Magnetic-drum delay line	6 words	500 µs	Magnetic drum	160 words	20 ms (max.)	Cards	—	—	Tax, *etc.*	—	—
1201 General purpose computer *639	38·4 kc/s	Binary	1 + 1 address	40	Serial	Fixed	2·5 ms	Multiplication 1 ms/binary digit plus 1·25 ms; division 1·25 ms/binary digit plus 1·25 ms	Valve	4 words	1·25 ms	Magnetic drum	1024 words	10 ms (average)	Cards	—	—	Sub-routines available	—	—
1202 General purpose computer *640	38·4 kc/s	Binary	1 + 1 address	40	Serial	Fixed	2·5 ms	as for 1201	Valve	4 words	1·25 ms	Magnetic drum	4096 words	10 ms (average)	Cards	—	—	Sub-routines available	Maths autocode	—
Leo III digital computer system *641	Asynchronous	Hexadecimal	Single address	10 Decimal digits (instructions 5 decimal digits)	Serial/parallel	Fixed point and full floating-point facilities	31–39 µs	Multiplication 184–367 µs; division 513–1888 µs	Core	1024 or 2048 words, or multiples of 4096 words up to 32,768 words	6·25 µs	See quick-access stores	—	—	—	—	—	Intercode	Cleo for commercial and mathematical work	Will incorp[or]ate all worthwhil[e] developme[nts] techniques [and] equipment
315	166⅔ kc/s	Binary-coded	Variable 1 or 2	1 to 8 words	Serial	Floating or	36–84 µs	Multiplication	Magnetic core	4000 to	1·3 µs	See quick access			Random access	Up to 16	Cram: up to		Neat and	Improved

	Alpha code	—	Punched tape, 20 char/s; also switches, keys and counters, and a wide range of other equipment	Punched tape, 20 char/s; typewriter, 10 char/s; provision for analogue–digital, digital–analogue conversion	Transistor	General purpose, industrial process control, and commercial applications	—	1·6 kW (basic computer)	Announced Sept. 1961	—	—	Small versatile inexpensive machine, particularly suited to data-logging. Off-line and on-line process control. Can act as a slave to KD9 or KD10. Use of Datapac transistorized logical elements. Comprehensive order-code of 64 functions. Automatic instruction-modification facilities. Wide range of peripheral equipment catered for
	Yes	—	See KDF9	See KDF9	Transistor	Medium/large-scale commercial data processing	1400 basic installation	10–30 kW (approx.)	1960	3	£130,000 upwards	System may be expanded with comprehensive range of on- and off-line equipment. Specially designed for large-scale commercial data-processing. True variable-length data recording
	Yes	—	Punched tape, 300 char/s (Ferranti TR5 tape reader)	Punched tape, 60 or 300 char/s (Teletype or Creed 3000)	Valve	Technical, scientific, and industrial calculations	40	18·5 kVA (basic installation)	1955	26 (3 installed abroad)	£39,000 (basic installation only)	Seven multiple accumulators
	Yes	—	As above, and punched cards, 200 cards/min (ICT 581 card reader) or 120 cards/min (Bull U.L.P.)	As above and punched cards 100 cards/min (ICT 582 card punch) or 120 cards/min (Bull U.L.P.)	Valve	Commerce, industrial data processing and calculating	500	45 kVA (comprehensive installation)	1960	12 (1 installed abroad)	£47,200 (basic installation)	Seven multiple accumulators. Pseudo off-line working between peripheral equipment available
	Yes	—	Punched tape, 300 or 1000 char/s; punched cards, 600 cards/min; Flexowriter	Punched tape, 60,110 or 300 char/s; punched cards, 100 cards/min, printing at 150,600 and 3000 lines/min; Flexowriter	Transistor	As for Pegasus 2	1000 (typical system)	40 kVA (typical system)	1959	12	£124,500 (basic installation	Time sharing and priority processing. Floating-point working available
	Yes	—	Any input equipment	Any output equipment	Transistor	Scientific and technical calculating	2000 (typical installation)	220 kVA (typical installation)	1960	1	£3m (typical installation)	Instructions may overlap and several accesses to the store may take place at once. Time sharing
	Yes	—	Punched tape, 250 char/s; punched cards, 120 cards/min; magnetic tape, 250 char/s; process-control and data-logging equipment	Punched tape, 60 or 300 char/s; punched cards, 120 cards/min; magnetic tape, 250 char/s; process-control and data-logging equipment	Transistor	Technical, educational, commercial calculations, and data-processing	25 (basic computer and desk)	600 W (basic computer)	1960	13	£18,450 (basic installation)	Eight multiple accumulators. Decimal displays, and desk-calculator-like hand switches
	—	—	Solid-state selectors to select virtually any number of analogue or digital inputs; analogue-to-digital converters	Digital to analogue converters; any number of analogue or digital outputs; logging equipment of any type	Transistor	Process control and data logging	12 (computer only)	3 kVA (computer only)	1960	2	£60,000 (typical system)	Eight multiple accumulators
	Yes	—	Punched tape, 1000 char/s; punched card, 650 cards/min	Punched tape, 110 frames/s; punched card, 250 cards/min; printer, 900 lines/min	Transistor	Commercial data processing	—	—	1960	See remarks for H800	£139,000	H400 tape can be read by an H800 machine and *vice-versa*; alternatively, the H400 can communicate direct to an H800 thus enabling satellite operation. Orthotronic control: automatically locates and adjusts errors in recording on tape. Variable block-length recording; magnetic tape unit also available, read/write 96,000 decimal digits or 64,000 alphabetic char/s
	Yes	—	As for H400	As for H400	Transistor	Commercial and technical data-processing	1200–2500	65 kVA	1960	See remarks	£395,000	During 1961 sales in U.S.A. expected to exceed £17m—all electronic computer systems. Magnetic tape unit available as for H 400. Capable of handling eight jobs at one time—it time shares over available jobs completely automatically without programmed intervention. Magnetic tape blocks completely variable in length. Distributed reading and writing
ramm- aids able	—	—	Punched tape, 18 frames/s; manual input registers (input channel: see remarks)	Punched tape, 20–60 frames/s; visual display (output channel: see remarks)	Transistor	Process control (on-line monitoring and control of industrial processes)	—	1·4 kW	1960/1961	—	Not disclosed	Through the input selection register and the input magnitude register, the computer can be programmed to select at random any input channel. Analogue to digital converters are available for input analogue information. The output selection and magnitude registers enable the computer to select at random an output channel and control a set-point, *etc.* Digital outputs are converted to analogue form where necessary. Macro-instructions augment 50 basic instructions—up to 63 requiring addressing can be selected
	Yes	—	Magnetic tape units, 15,000–62,500 char/s; 3 × 7500 card-readers, 500 × 80-column cards/min	Magnetic tape units, 15,000–62,500 char/s; 3 card punches, 250 cards/min; printer, 120 lines/min	Transistor	Integrated accounting precedures, production control, insurance *etc.*	900	35 kVA	1958	—	—	Three accumulators of 10 digits; add accumulator to storage; add storage to accumulator. Automatic priority processing simplifies parallel programming. Table look up feature. All input/output operations fully buffered. Up to 4 tape input/output operations may be carried out simultaneously with processing. Programming systems autocoder; Fortran; Report program generator, Cobol
rks	Yes	—	As for 7070 DP	As for 7070 DP	Transistor	Commercial and scientific computing at high processing speeds	900	35 kVA	1960	—	—	All 7070 programs fully compatible with 7074. Twice as fast as 7070 for commercial application; ten times as as fast as 7070 for floating-point scientific work; fixed-point operations, six times as fast as 7070
	Yes	—	Punched tape, 150 alphanumeric char/s; punched cards, 250 cards/min (buffered)	Punched tape, 15 char/s; card punch, 125 cards/min; typewriter, 10 char/s	Transistor	Research, engineering, design, statistics, simulation	350	5 kVA	1959	—	£30,000–£50,000	Table look-up arithmetic. Simple two-address programming; programming systems include a symbolic assembler, Gotran and Fortram which are of algebraic, problem-orientated languages. Variety of programs available for engineering, scientific and mathematical applications
an, l, rt ator, l	Yes (see previous column)	No public announcement	Punched cards, 800 cards/min; punched tape, 500 char/s; magnetic tape, 7200 to 62,500 char/s; optical sorter/reader, up to 480 char/s; keyboard/inquiry station, up to 20 char/s	Card punch; tape punch; magnetic tape (as in previous column); printer: 600 lines alphanumeric, 1285 lines numeric; inquiry typewriter 20 char/s	Transistor	Commercial and scientific	350	24 kVA	Sept. 1961	—	—	Variable-length table look-up. Comprehensive editing. Alphanumeric 'high-low-equal' compare. Tape/Ramac facilities
ion	Cobol	—	Punched card, 600 cards/min	Card punch, 100 cards/min; printer, 600 lines/min	Transistor	Commercial	576	6 kW (basic machine)	May 1960	—	£120,000	Decimal- and sterling-arithmetic extension to Cobol
nd rsion	—	—	Punched card, 100 cards/min 240-gang punch	Card punch, 100 cards/min	Valve	Commercial and mathematical problems	44	13 kW	1956	Mostly rented	£25,000	Program facilities
etc.	—	—	Punched card, 120 cards/min	Card punch, 120 cards/min	Valve	Commercial	36	—	1954	—	£20,000	Decimal and sterling arithmetic
es ble	—	—	Punched card, 100 cards/min	Card punch, 100 cards/min; also printer	Valve	Commercial and mathematical problems	65	11 kW	1954	40	£34,000	Binary input/output
es ble	Maths autocode	—	As for 1201	As for 1201	Valve	Commercial and mathematical problems	83	14 kW	1957	50	£42,000	Binary input/output
ode	Cleo for commercial and mathematical work	Will incorporate all worthwhile developments in techniques and equipment	Magnetic tape, 22,500–90,000 char/s; punched tape, 1000 char/s; punched cards, 400 or 600 cards/min	Magnetic tape, 45,000 or 90,000 char/s; punched tape, 100 char/s; punched cards, 100 cards/min; printers, 150,400 or 1000 lines/min; typewriter, 10 char/s	Transistor	All commercial and mathematical data processing	1100	30 kW	July 1960	4	£100,000–£250,000 approx.	Automatic arithmetic in any desired radix; all actions modifiable; special actions for editing and unpacking data: additional action microplanes can be devised and fitted on site to provide instructions for special requirements; arithmetic concurrent with multi-channel input and output; automatic time-sharing of store; concurrent operation of the two or more programs; extensive built-in checking facilities; very flexible 'building-block' construction
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1961	40	[illegible]	Random-access units with changeable cartridges (Cram) used for

paper tape input, core-store memory in 803 computer, which is central processor of 609. *Analogue-to-digital converters*: . and thus running on-line and off-line work virtually simultaneously.

*679 Optimat (an optimizing controller). This is an end-point optimizer; that is, it searches continuously to maximize the index that it is given, as a measure of its success. This index might be a flowrate, a measure of cost, or some more complex function. The Optimat experiments by reading the index of performance, altering the set-point of a conventional controller by a small amount, allowing the plant time to settle and then finding whether the index has improved or deteriorated; from this result it decides its next move. Its action may be likened to that of a man attempting to find the summit of a hill without a map and in darkness—if he walks up the hill, ignores mole-hills, *etc.*, and changes direction if necessary, he will arrive at the summit. Design is flexible and based on the use of the Elliott Minilog transistorized logical units. System is fully self-contained. The input is normally a voltage which is digitized by the Optimat; alternatively, shaft-rotations may be digitized by coded disks. The index of performance is normally calculated by analogue methods if several variables are involved. Applications include distillation columns, heating or drying systems in paper mills, mineral ball-mills, blending of viscous liquids, *etc.*

* Circle appropriate number on reply card facing page 164 for further details

Computers Ltd	computer systems *641	
National Cash Register Co. Ltd	315 *642	166
Standard Telephones and Cables Ltd	Stantec computing system (based on Zebra) *643	128 k

Manufacturer	Name and description	Capacity of typical installation: Amplifiers	Coefficient networks	Multipliers	Resolvers	Function generator	Other units	Static component accuracy: With oven control %	Without oven control %	Operational procedure: Method of working	Amplifier network configuration	Change of coefficients of amplifier network	Patching	Initial conditions	Automatic time scale change facility	Hold facility
Associated Electrical Industries Ltd	A.E.I. 955 General purpose computer *646	See remarks	—	—	—	—	—	—	0·1 or 1·0	Single shot, repetitive, or continuous from 0·1 to 12 s	Feedback impedances contained in adder units. 3 amplifiers may be coupled into each unit	Feedback capacitors and resistors switched. Input resistors selected when patching	Central with cords	Inserted on external patch socket	—	Manual voltage-comparator or time hold available
Daystrom Ltd	Daystrom-Heath Kit, Model ES2 *647	15	30 potentiometers	—	—	Separate unit	—	—	None	Repetitive 0·6–6·0 c/s	Selected on patch panel	Selected on patch panel	Central with cords	Relay *via* external voltage	—	—
Electronic Associates Ltd	Pace TR5 *648	10	—	—	—	—	Power unit, meter and balance facilities	—	0·1	Single shot and repetitive	Selected by patch cords and plug-in components	Bottle plug, or by means of function switches	Sectionalized patch panels, cords, and plug-in resistors	Potentiometer connected to integrator	No	Yes
	TR10 *649	10	10 potentiometers	—	—	—	One comparator, (see remarks), four integrator networks, reset hold, and operate console with all control circuits	—	0·1	As for TR5	As for TR5	As for TR5	As for TR5	As for TR5	No	Yes
	221R *650	20, with 6 input-networks	20 potentiometers	—	—	—	Console with all power and control facilities. Reference and selection system	0·005	—	Single shot and repetitive	Bottle plug	As for TR5	Central panel with cords and plugs	As for TR5	Yes	Yes
	231R *651	40 (capable of extension to 700)	40 potentiometers	—	—	—	Console with all power and control facilities. Automatic selection and read-out facilities	0·005	—	Single shot and repetitive with 10 ms sweep display on 12 channel c.r.t.	Bottle plug	As for 221R	As for 221R	As for 221R	Yes	Yes
Elliott-Automation Ltd	G-PAC (mk I) *652	20 (may be extended to 120 by connecting cabinets)	—	—	—	—	—	—	1	Single shot, 1 s upwards	Plug-in components	Change of plug-in components or by potentiometers	Patch cords between units	Initial charge applied to integrating capacitor with input disconnected	No	No
	G-PAC (mk II) *653	25 (may be extended to 60 by direct expansion)	—	3	—	—	—	0·1	—	As for mk I	Patched at central panel	As for mk I	Central patch board	As for mk I	No	Yes
	Minipac	10	—	—	—	—	—	—	1	As for mk I	As for mk I	As for mk I	Patch boards	As for mk I	No	No
E.M.I. Electronics Ltd	Emiac 11 *655	18	24 potentiometers	—	—	—	—	—	0·1	Single shot (30 s) or repetitive 1, 2 or 5 s/cycle	Contained in units which plug into front of the module	Computing resistors and capacitors are fixed in *C* boxes (see remarks) by screws	Removable patch board	Presets are set up by a potentiometer mounted on all integrator *C* boxes	All integrating *C* boxes have a 3-position switch on front panel—selection of 1·0, 0·1 or 0·01 μF	Yes

mputer system 641	ous			digits (instructions 5 decimal digits)	parallel	and full floating-point facilities		division 513–1888 µs		or multiples of 4096 words up to 32,768 words									and mathematical work	worthwhile developments in techniques and equipment
2	166·7 kc/s	Binary-coded decimal	Variable 1 or 2 address	1 to 8 words (each 12 bits plus parity)	Serial, parallel, or serial-parallel	Floating or fixed	36–84 µs	Multiplication, 288–2081 µs; division, 1020–1962 µs	Magnetic core	4000 to 80,000 characters	1·3 µs	See quick access store and remarks	—	—	Random access magnetic cards and magnetic tape	Up to 16 random-access units (Cram): over $5 \cdot 5 \times 10^6$ char/cartridge of 256 cards. Up to 8 tape-units (max. $21 \cdot 1 \times 10^6$ char/3600 ft reel)	Cram: up to 200 ms time shared; re-access 23 ms (ave.) Tape: transfer rate 60 kc/s (max.)	—	Neat and Neat-Cobol	Improved internal operations due to improved hardware. Faster peripherals. Inquiry system, optical reader
tac puting em (based on ra) 0	128 kc/s basic	Binary	Two address plus 15 functional digits	33 binary digits (32 plus sign)	Serial	Fixed	312 µs	Multiplication, double-length product, 936 µs plus 5 ms drum-access in some cases; division is programmed, 40 ms including access time	Ferrite store; also 12-word fast-access store	Blocks of 1024 or 2048 words 8192 words total	Magnetic drum	8192 words		10 ms (max.)	Magnetic tape	Three types available: approx. max. capacity $2 \cdot 8 \times 10^6$ words	Read/write (128-word block) 70 ms. Actual tape-speed 20,000 char/s	Yes	Yes	Transistors

* Circle appropriate number on reply card facing page 164 for further details

ANALOGUE COMPUTERS

			Measurement, display and recording						Computing amplifiers								Passive coefficient networks					
			Measurement		Display		Recording															
Hold facility	Check facility	Remote setting of coefficients	Type	Accuracy %	Type	Accuracy %	Type	Accuracy %	Valve or transistor	Open loop gain at zero frequency	Phase error under typical closed loop conditions	Equivalent input noise and drift	Equivalent input impedance or input current	Max capacity loading	Max output voltage	Max output current	Continuous or discrete	Resolution accuracy %	Manual or servo set	Input impedance	Output impedance	
Manual voltage-comparator or time hold available	—	None	Digital voltmeter	0·05	Synchronized display oscilloscope digital voltmeter	— 00·5	Pen recorders	—	Valve	4×10^4	Unity band-width 120 kc/s<	Noise 100 µV r.m.s.; drift <± 50 µV	Current $<5 \times 10^{-11}$ A	Dependent on feedback conditions	± 100 V	20 mA	Continuous	Ten-turn helical potentiometer 0·1% linearity	Manual set, using null indicator on master potentiometer or digital voltmeter	30 kΩ	≤7·5 kΩ	Servo Hall e
—	Meter	None	Meter	—	—	—	—	—	Valve	5×10^4	1° at 1200 c/s	Noise 2 mV Drift 0·5 mV	—	—	± 100 V	10 mA	Continuous	0·1	Manual set using null indicator to divider network	—	—	None: plugg extern
Yes	Partial	None	Meter	0·1	—	—	X-Y plotter	—	Transistor	30×10^6	Inverter 0·01° at 100 c/s	Noise 40 µV drift 25 σ V/s	—	Infinite	± 10 V	25 mA	Continuous	0·1	Manual	5 kΩ	≤1·25 kΩ	Diode squa Servo
Yes	Partial	None	Meter	0·1	—	—	X-Y plotter	—	Transistor	30×10^6	Inverter 0·01° at 100 c/s	As for TR5	—	Infinite	± 10 V	25 mA	Continuous	0·1	Manual	5 kΩ	≤1·25kΩ	As f
Yes	Complete	Manual keyboard and punched tape	Meter: high-speed 5-digit digital voltmeter	—	X-Y plotter	—	Mechanical printer	—	Valve	$1 \cdot 35 \times 10^8$	Inverter 0·1° at 100 c/s	Noise 500 µV; drift 3·5 mV/min	—	Infinite	± 100 V	30 mA	Continuous	0·1	Both	30 kΩ	≤7·5 kΩ	As f Also
Yes	Complete	As for 221R	As for 221R. Also punched-tape, X-Y plotter, and 8-channel recorder	—	X-Y plotter 8-channel recorder	—	Printer, plotter and 8-channel recorder	—	Valve	$1 \cdot 35 \times 10^8$	As for 221R	As for 221R	—	Infinite	± 100V	30 mA	Continuous	0·1	Both	30 kΩ	≤7·5 kΩ	As f
No	Static check only	None	Meter	1	Not provided as integral part of computer	—	—	—	Valve	5×10^8	Inverter 2×10^{-3} rads at 600 c/s	Noise 0·5 mV; drift 0·5 mV	Current 2×10^{-8} A	Input 100 pF with 2·2 MΩ feedback resistor; output 0·015 µF with 2·2 MΩ feedback resistor	± 100 V	10 mA	Continuous ten-turn helical potentiometer	0·1	Manual	20 kΩ	≤5kΩ	Serv pot
Yes	Static and dynamic checks	None	Null meter	0·02	As for mk 1	—	—	—	Valve	25×10^6	As for mk I	Noise 0·5 mV; drift 50 µV	Current 10^{-10} A	As for mk I	± 100 V	20 mA	As for mk I	0·1	Manual	20 kΩ	≤5 kΩ	Serv pot
No	Static check only	None	Not supplied	—	—	—	—	—	Valve	5×10^8	As for mk I	As for mk I	Current 2×10^{-9} A	As for mk I	± 100 V	10 mA	As for mk I	0·1	Manual	20 kΩ	≤5 kΩ	Dio squ
Yes	Facilities for controlling 3 sets of six amplifiers individually	None	Meter: null-balance against precision helipot	0·2	Ten inch display oscilloscope with time sharing facilities on X and Y deflection; 100 s long-persistence tube	—	—	—	Valve	7×10^8	Inverter 6° at 5 kc/s	Noise 1 mV; drift <100 µV	Current 10^{-10} A	Input 100 pF; output 0·01 µF	± 125 V	10 mA	Wire-wound potentiometer	0·02	Manual	100 kΩ	Up to 100 kΩ	Ti dri

and mathematical work	worthwhile developments in techniques and equipment	cards, 400 or 600 cards/min	cards, 100 cards/min; printers, 150,400 or 1000 lines/min; typewriter, 10 char/s		data processing					approx.	for special requirements; arithmetic concurrent with multi-channel input and output; automatic time-sharing of store; concurrent operation of the two or more programs; extensive built-in checking facilities; very flexible 'building-block' construction
Neat and Neat-Cobol	Improved internal operations due to improved hardware. Faster peripherals. Inquiry system, optical reader	Paper tape, 1000 char/s; punched cards, 400 and 2000 cards/min; mag. document sorter, 750/min (buffered); Cram, 100 kc/s; magnetic tape, up to 60 kc/s; console typewriter	Paper tape, 110 char/s; punched cards, 100 and 250 cards/min (buffered); line printer, 900 lines/min (numeric), 680 lines/min (alphanumeric buffered); magnetic tape; Cram; console typewriter	Transistor	Commerce; some scientific applications	900	22 kVA (average system)	1961	40	£97,000–£250,000	Random access units with changeable cartridges (Cram) used for backing store and may be used for main store. Time-sharing facilities with automatic program interruption. Automatic selection of subroutines for peripheral conditions
s	Transistors	Paper tape, 300 char/s and 800 char/s; punched cards, 300 cards/min	Monitor teleprinter, 10 char/s; punched tape 100 char/s; line printers, 150 lines/min	Transistor	General purpose	Cubicles 12, desk 50	2·5 kVA (basic computer	Mar. 1958	See remarks	£30,000 for basic computer	Forty Zebra computers have been installed; the first Stantec system was installed this year, and nine more are on order. Simplified coding systems available include simple code with full floating-point facilities and Seal (Standard electronic accounting language)—a compiler scheme allowing the computer to accept ordinary language statements

further details

		Multipliers			Resolvers			Function generators			Other units									
…ut …dance	Output impedance	Type	Static accuracy %	Phase error at typical frequency	Type	Static accuracy %	Phase error at typical frequency	Type	Static accuracy %	Phase error at typical frequency	Type	Static accuracy %	Phase error at typical frequency	Price of typical installation or of computing units	First put on market	Number sold	Floor area ft²	Power consumption	Main applications	Remarks and special features
Ω	≤7·5 kΩ	Servo	0·3	<1° at 10 c/s	One resolver section in servo multiplier	0·3	<1° at 10 c/s	Diode: 1–20 segments, or 2–10 segments with four amplifiers	Better than 1	Negligible at 100 c/s for most functions	Two dead space and limit sections; one comparator unit; relay sections	—	—	On application for specific requirements	1959	—	—	<1 kW per cubicle	General purpose and servo simulation problems	To customers' specification; each cubicle contains up to 30 amplifiers and associated components or equivalent in non-linear units. Operating temperature to 60°C ambient. Large installations should be force cooled. Special circuits may be patched externally
		Hall effect	0·3	—																
	—	None: can be plugged in externally	—	—	None: can be plugged in externally	—	—	Diode	—	—	—	—	—	£490 (ES2 sold as a kit of parts to be assembled)	1957	—	Desk size, 4	420W	Educational and industrial	An ES1 kit is also available, comprising nine amplifiers and associated components—cost about £100
	≤1·25 kΩ	Diode (quarter square type)	0·1	—	Fixed, diode function generator	0·2	—	Fixed diode generator for squaring and square root	0·1	—	Under development	—	—	£600	1960	30	Desk 0·5	10 W	Process control investigations and general studies	May be extended to 30-amplifier machine. Temperature effect—drift 0·5 μV/degF. Portable
		Servo	0·1	—	Servo	0·2	—	Diode arbitrary function generator	0·1	—										
								Tapped servo-driven potentiometer	0·1	—										
Ω	≤1·25kΩ	As for TR5	—	—	As for TR5	—	—	As for TR5, also curve-follower	—	—	As for TR5	—	—	£1700	1959	125	Desk 1·0	30 W	General	May be extended to 60-amplifier machine. The comparator compares a variable input-voltage to an arbitrary bias-voltage and causes a switching operations to be performed. Portable
kΩ	≤7·5 kΩ	As for TR5	0·02	—	As for TR5, also servo rate	0·02	—	As for TR5; also curve-follower for function of two variables	0·02	—	Under development	0·005	—	£9000	1959	50	14	3 kW	General	May be extended to 140-amplifier machine. High precision machine
		Also time division	0·02	—																
kΩ	≤7·5 kΩ	As for 221R	—	—	As for 221R	—	—	As for 221R; also digitally-set diode function generators	0·02	—	Under development	0·005	—	£13,000	1959	800 (including some earlier models)	14	4 kW	General	High precision machine. Note: 25 special machines housing 900 amplifiers have been sold, with characteristics similar to those of 221R and 231R
Ω	≤5kΩ	Servo 3-gang potentiometer	± 0·5	—	Not available at present			Diode: fixed or arbitrary generators	0·25	<1° at 500 c/s for $y = x^2$	Pure time delays; automatic rescaling units	—	—	On application	1955	40	4	1·2 kW for 20 amplifiers	Aircraft, guided weapons, and nuclear-power systems	General purpose, real-time non-repetitive machine
kΩ	≤5 kΩ	Servo 6-gang potentiometer	± 0·25	—	Not available at present	—	—	As for mk I	—	—	As for mk I			On application	1960	—	As for mk I	As for mk I	As for mk I	General purpose, real-time, non-repetitive machine; may be extended to 120 amplifiers by coupling machines
Ω	≤5 kΩ	Diode (quarter squares)	<0·3	<1° at 500 c/s	As for mk I	—	—	As for mk I	—	—	As for mk I	—	—	On application	1957	5	—	—	As for mk I	May be extended to 15 amplifiers
kΩ	Up to 100 kΩ	Time division driving 6 switches	0·1% or 25 mV	3–5° at 10 c/s	None	—	—	Diode (11 segments)	Setting accuracy 100 mV	Negligible	—	—	—	Single module and power unit £2500–£3000	1959	100	15 for desk and power unit	600 W (one module)	Research and scientific work	Temperature variation with respect to amplifiers should be less than 10 degC. Spare patch-boards permit problem storage. Basic unit is a

Ltd										or 5 s/cycle	into front of the module	fixed in C boxes (see remarks) by screws		on all integrator C boxes	switch on front panel—selection of 1·0, 0·1 or 0·01 μF	
The English Electric Co. Ltd	Lace mk 11 *656	32	50 potentiometers	2	—	2	Display unit, null meter and power supplies (this capacity called a brick unit)	—	0·1	Single shot (2 min) repetitive (30 c/s–0·2 c/s)	Patching and selection of component trays	Patching and selection of component trays	Removable patch panel	By 10-turn helical pots (separate from coefficient pots)	No	Yes
Feedback Ltd	System simulator type SS.110 mk II *657	3 double-unit amplifiers (A_1 and A_2)	Not specified	—	—	—	—	—	1	Single shot 0·1 to 50 s or repetitive up to 50 c/s	Adding units 4 input- and 4 feedback-resistors incorporated; integrating units; separate *RC* units	For integrators 11 switched values of *R*, and 9 switched values of *C*	Plug leads between front-panel sockets on individual units	Voltage from potentiometers fed from stabilized supply	No: possible by manual switching	Yes
General Precision Systems Ltd	— *658	30 type-BDX	15 sum/integrate feedback units; 15 sum-feedback units; 40-ten turn potentiometers; 3-padding units	3 low-speed (3 products), 3 mark space	—	6 limiters and associated amplifiers	Digital voltmeter, control panel and patch panel, and power supplies	—	0·1 or 1	Single shot or repetitive 500 c/s to 0·0005c/s	Switching on feedback boxes	Switching or adjustment of potentiometers	Central removable patch panel	Voltage fed to integrating capacitors by a system of relay contacts	No: four position selector switch on each unit time constants 1, 0·1 and 0·01 s	Yes
Miles Electronics	Marc (Miles analogue reactor computer) *659	Unlimited (special and general purpose computing units)	—	—	—	—	—	—	Up to 0·01	Single shot or repetitive (seconds to several hours)	Shorting link and patch cords on front panels	As previous column	As previous column or removable patch panel	By push-button remote control	No	Yes
Newmark Instrument Ltd	Model 3000 *660	10 amplifier basic, with clamping diodes	Not specified	—	—	—	—	—	0·1 or 1 (plug-in components)	Single shot 0·1 to to 30 s. Cyclic reset generator 0·05 to 16 s	Plug-in components on patch panel	As previous column	Central patch panel (removable)	5 built-in pots for each 10-amplifier assembly linked by relays	No	Yes
	Model 3400 *661	10	Not specified	—	—	—	Null voltmeter, cyclic reset generator, selection of non-linear modules	—	0·1 or 1 (plug-in components)	Repetitive 0·1 to 10 s; typical computing period 0·1 s to 5 min (single shot)	Plug-in components on patch panel	As previous column	As for 3000	As for 3000	No	Yes
Bruce Peebles and Co. Ltd	No standard computer available: component parts sold (see remarks) *662	—	—	—	—	—	—	—	—	—	—	—	Plugs and sockets on front panels of units	—	—	—
Short Brothers & Harland Ltd	Simlac *663	120 summer/integrator	180 potentiometers (servo-set), 12 potentiometers (manually set)	20 servo	—	8 limiter/dead-zone units 12 fixed-function units, 9 arbitrary function generators	All ancillary control and measuring equipment, print-out facilities	0·01	—	Single shot and repetitive 1 and 10 s	Pin-in patch board	Pin-on patch board	Removable patch board using pins only, (i.e. no cords)	Voltage applied to integrator capacitors by control circuits	Optional	Yes
	Educational *664	6	12 potentiometers	—	—	—	—	—	1	Single shot and repetitive 0·1 and 1 s	Plug-in components	As for previous column	Units plugged into display board	Initial condition voltage added in following amplifier	No	No
	General purpose *665	18	18 double scaling units	—	—	—	All ancillary control, measuring, and recording equipment	—	1	Single shot and repetitive 1/30–1 s	Manual ganged switching	As for previous column	Central patch panel	As for educational computer	No: manual change by changing selector position on each unit	No
The Solartron Electronic Group Ltd	SCD 10 *666	20 type AA 1054	24 potentiometers	2 servo-multipliers or 2 resolvers	—	—	—	—	0·1 resistors; 0·5 capacitors	Repetitive 1, 2 or 5 s	Patching	Patching	Front patching	Initial charge on feedback capacitor	No	No
	SCD 24 *667	24 type AA 1054	48 potentiometers	6 electronic multipliers	—	6 diode function generators	—	—	0·1	Repetitive: fast, using solid-state logic circuits; single shot and pause conditions 1–100 s	Feedback components selected by front panel switches	As previous column	Central removable patch panel	As above	No	Yes
	SC30 *668	30 type AA 1023	60 potentiometers	4 servo-multipliers or resolvers	—	2 diode function generators	—	—	0·1	Repetitive and single shot 1–100 s	Patching	As previous column	Central removable patch panel	As above	Decade change using one key switch	Yes
	SC 100 *669	100 type AA 1023	160 potentiometers	12 electronic multipliers each with 2 slave-channels or equivalent capacity	—	6 diode function generators	—	0·01	—	—	Patching	Patching	Central removable patch panel	As above	Two-decade change by single switch	Yes
Westland Aircraft Ltd	Installation to specification *670	—	—	—	—	—	—	—	0·5	Single shot	Shorting links on patch panel	Coefficient pots	Shorting links and cords on patch panel	As above	—	Yes

sets of six amplifiers individually		precision helipot		time sharing facilities on X and Y deflection; 100 s long-persistence tube							drift $<100\ \mu V$										
All necessary metering provided	None	Null meter with decade switches	0·1	Built-in c.r.t., null meter or digital voltmeter	—	Print-out facilities if digital voltmeter used	—	Valve	6×10^7	Inverter 0·5° at 100 c/s	Noise 1 μv; drift 100 μV	Current 10^{-9} A	Input 5000 pF; output 0·5 μF	± 150 V off-load	50 V into 68 kΩ (output impedance of open-loop amplifier 10 kΩ)	Ten-turn wire-wound potentiometer	0·1	Manual	50 kΩ	⩽12·5kΩ	Electro[...] Servo
—	None	Meter	—	—	—	—	—	Valve	A_1, +120 reduced to +1 or +20 by internal feedback; A_2, 150; combined = 3000 (max.)	—	—	Current 10^{-9} A	Input 25 pF; output 350 pF	± 50 V	2 mA	Potentiometer	0·5	Manual	—	—	—
Run-up of all integrators and check by digital voltmeter at time t	None	Digital voltmeter (4 digits)	—	Oscilloscope (double beam)	—	Print out facilities provided if required	—	Valve	B.D.X. 37×10^6	Inverter 10° at 1 kc/s	Drift 100 μV	Current 5×10^{-11} A	Input 1000 pF at unity gain; output 0·05 μF	± 100 V	10 mA	One-turn or 10-turn potentiometer	0·2 (1-turn) 0·01 (10-turn)	Manual	—	—	Low-spe[...] pot. (6-[...] High-spe[...] pot. (3-[...] Mark s[...] 4 produ[...]
Yes	None	As required	—	—	—	—	—	Valve	730×10^7	—	Noise 5 mV; drift 100 μV	Current 10^{-10} A	Input 250 pF; output 100Ω in series with 1μF, with 1 MΩ feed-back resistor	220 V p–p at 40 c/s into 10 kΩ load	5, 15, and 35 mA; front-panel selection	Ten-turn potentiometer and fixed resistors	—	Manual	—	—	Quarter s[...] Servo
Balance over-load indication; visual problem-lay-out check	None	Meter: null voltmeter 0·1 V full scale	1	—	—	—	—	Valve	$>10^4$ at ± 100V $>5 \times 10^2$ at ± 50 V	Inverter 1° at 10 kc/s	Noise <1 mV; drift 4 mV/h as inverter	Current $<10^{-9}$A	—	± 100 V	5 mA	Potentiometer helical	1% or 0·5% linearity setting to 4 significant figures	Manual	100 kΩ to 10 MΩ 1% or 0·1% steps	—	Two-cha[...] mark sp[...] electroni[...]
As for 3000	None	As for 3000	—	Oscilloscope or X-Y plotter external	—	—	—	Valve	$0·5 \times 10^7$ (10^3 in chopper)	—	Noise <2 mV; drift 100 μV/ week	Current 3×10^{-11} A	Input and output 1000 pF negligible effect	± 175 V	13 mA at ± 100 V; 1 mA at ± 175 V	100 kΩ ten-turn helical pots 0·5% linearity	4 significant figures or 0·1%	Manual	—	—	As for 3[...] except hi[...] accuracy [...] able
—	—	—	—	—	—	—	—	Valve	$>3 \times 10^3$	—	Noise <5 mV; drift 10 mV	—	—	± 100 V	5 mA	Scaling unit: scale factors, 1–100; capacitors: 0·1 and 1·0 μF discrete steps Selection of appropriate interconnexion	1	Manual	—	—	—
								Valve	$>3 \times 10^7$	Band-width 16 kc/s at gain of 10	Noise 200 μV; drift 100 μV	—	With 1 MΩ feed-back resistor, 2 μF at output with 250 pF at input	± 100 V	5–10 mA						
Operational and patch-panel plugging	Yes: manual and punched tape	Digital voltmeter	0·01	Oscilloscope	3	Pen recorder, print-out facilities	0·1	Valve	10^8	Inverter <0·05° at 100 c/s	Noise 200 μV; drift 25 μV/ month	Current 10^{-11} A	Input 2000 pF; output 10,000 pF	± 125 V	10 mA	Ten-turn helical potentiometer	0·01	Servo set or manual	100 kΩ	100 kΩ or 1 MΩ	Servo Quarter s[...] Time divi[...]
No	None	—	—	Oscilloscope	3	Pen recorder	1	Valve	$2·4 \times 10^6$	Inverter <0·25° at 100 c/s	Noise 50 μV; drift 50 μV month	Current 6×10^{-10} A	Input 1000 pF; output 4000 pF	± 50 V	5 mA	Continuous potentiometer	1·0	Manual	100 kΩ	1 MΩ	None
No	None	Null meter	0·1	Oscilloscope	1	Polaroid camera	1	Valve	10^7	Inverter <0·2° at 100 c/s	Noise 200 μV; drift 100 μV	Current 5×10^{-12}A	Input 2000 pF; output 5000 pF	± 50 V	5 mA	Discrete range of decade resistors in each section of a scaling unit	1·0	Manual	100 kΩ approx.	1 MΩ	Servo Quarter s[...]
Problem check facility	None	Null potentiometer	0·1	Nil	—	—	—	Valve	10^7	Not available at present	Noise <100 μV; drift <100 μV	Current 5×10^{-11} A	Input 1000 pF; output 10,000 pF with 1 MΩ feed-back resistor	± 100 V	10 mA	Ten-turn helical potentiometer	0·01	Manual	30 kΩ	⩽7·5 kΩ	Servo Electronic space
Problem check facility	None	Digital voltmeter	0·01	Optional	—	Print-out directly from digital voltmeter including complete address system	—	Valve	10^7	As above	As above	As above	As above	± 100 V	10 mA	Ten-position switch with concentric fine-control potentiometer	0·01	Manual	100 kΩ	⩽25 kΩ	Electronic space
Problem check facility, also input current to each integrator monitored	None	Digital voltmeter	0·01	Optional	—	Printer coupled to digital voltmeter optional extra	—	Valve	10^8	45° at 25 kc/s with gain of 10	Noise 30 μV; drift 20 μV	Current 5×10^{-11} A	Input 250 pF output 0·07 μF with 1 MΩ feed-back resistor	± 100 V	14 mA	Three-turn helical potentiometer	0·01	Manual	30 kΩ	⩽7·5 kΩ	Servo
Problem check; integrator input current and rate checks	Yes: punched tape and output standard	Digital voltmeter	0·01	Four-channel display oscilloscope (17 in)	—	X-Y plotter and 10 channel u/v recorder. Printer coupled to digital voltmeter with complete address system	—	As above	As above	As above	As above	As above	As above	As above	As above	Ten-turn helical potentiometer	0·005	Servo or manual	100 kΩ	⩽25 kΩ	Electronic space
Static check only	None	—	± 2	—	—	2-channel pen recorder	—	Valve	$>10^8$	—	Noise <1 mV; drift <50 μV	Current 10^{-10} A	Input 250 pF; output 10,000 pF	± 50 V	10 mA	Potentiometer	0·1	Manual	50 kΩ	—	Quarter s[...]

* Circle appropriate number on reply card facing page 164 for further details

								100 mV					£2500–£3000			unit			should be less than 10 degC. Spare patch-boards permit problem storage. Basic unit is a single module comprising 18 amplifiers, 24 potentiometers, patch panel and control panel. Module stands on a desk. Input and feedback impedances are contained in plug in units called *C* boxes. These plug into the module front, and amplifiers into the rear. Capacity of typical installation 1–6 modules. Large installations to customers' requirements
⩽12·5kΩ	Electronic	0·25	1° at 100 c/s	Servo	1	2° at 8 c/s	Diode (variable slope and breakpoints with round-off)	—	1° at 100 c/s	—	—	—	£7000	1959	25	18	2 kW	Aerodynamics, control systems, technical colleges, *etc.*	Patch panels and control systems may be inter-connected for large installations
	Servo	0·3	2° at 8 c/s																
—	—	—	—	—	—	—	Control unit provides step and ramp functions and 50 c/s square wave	—	—	—	—	—	£375	1961	2	—	250 VA	Educational and general laboratory use	Front panels of units clearly marked for ease in tracing and identifying component values
—	Low-speed servo-pot. (6-gang)	0·3	—	—	—	—	Diode (10 segments)	± 2	± 2% up to 2 kc/s	Trip amplifiers; special network feedback-units for pre-wiring of special or standard transfer-functions	—	—	£7000	1959	6	12	3 kW	Aerodynamics, nuclear and chemical research, environmental testing	May be extended by 100% by additional racks; unlimited extension by additional groups. Prefabricated modules allow for construction to specific requirements
	High-speed servo-pot. (3- or 6-gang)	0·25	1·5° at 10 c/s				Limiters	—	—										
	Mark space up to 4 products	0·1% or 25 mV	—																
—	Quarter squares	1	1° at 100 c/s	In development stage	—	—	Diode (16 segments)	0·1	1° at 100 c/s	Specialized units for nuclear studies	—	—	Amplifiers £50 each; student computer from £1308; 100-amplifier reactor computer £23,305	1960	9 of varying capacity	—	—	Nuclear engineering and research	Precision special-purpose units for reactor computation flexibility Control system units
	Servo	—	—				Servo-driven loaded potentiometer	—	—										
—	Two-channel mark space electronic	± 0·25	<2·5° at 100 c/s	None	—	—	Diode (24 segments) extra module	0·1	—	Transportation delay generator (0·5–10 s)	—	—	£600 to £1400	Late 1959	8	Desk-top version 4; rack version 2	350 W (basic model)	Aerodynamic, nuclear, and advanced physical problems	Module construction for non-linear operations. Extendable to 30 amplifiers in groups of 10
—	As for 3000 except higher accuracy is available	—	—	—	—	—	—	—	—	—	—	—	£1200 to £3000	1959	12	As for 3000	250 W (basic model)	Scientific investigations, education, operational research	Extendable to 30 amplifiers in groups of 10. Modular construction. Plug-in dual amplifiers Removable patch panel
—	—	—	—	—	—	—	Diode (4 segments)	—	—	Noise generator; power amplifier; phase-sensitive detector; sine-wave generator, 9 c/s to 9 kc/s	—	—	—	—	—	—	—	—	Computers using standard parts can be built to individual requirements. Components include amplifiers, oscillators, etc; initial condition unit also available
100 kΩ or 1 MΩ	Servo	0·2	—	As for servo multiplier	—	—	Diode, 20 or 2 × 10 segments.	0·1	0·1° at 100 c/s	—	—	—	£50,000	1961	—	—	—	General scientific applications	Basic computer may be extended to specific requirements. Removable patch without use of cords—use of shorting pins. A smaller version 'Simlac Minor', with capacity of about one third that of Simlac is available—cost £10,000
	Quarter squares	0·2	—				Also fixed diode function generators	—	—										
	Time division	0·01	0·1° at 100 c/s																
1 MΩ	None	—	—	None	—	—	Diode 10 or 20 segments	—	—	—	—	—	£900 not including measuring and recording equipment	1960	—	—	—	Educational or general applications	A machine specially designed for demonstration purposes. Good visual representation of interconnexions and types of units on display board—suitable for class-room audience
1 MΩ	Servo	1	—	As for servo unit	—	—	Diode (20 segments)	1	0·05° at 100 c/s	—	—	—	£5300	1953	—	—	—	General purpose	Patch panel uses two-pin shorting plugs—no cords. Easy check on set-up. Amplifier computing impedances an integral part of amplifier unit. Function and component values selected by switches. Facilities for interconnecting several machines
	Quarter squares	1	0·5° at 1000 c/s				Fixed diode function generators	1	0·05° at 100 c/s										
⩽7·5 kΩ	Servo	0·25	<1° at 100 c/s	Servo type with 5 sections: 3 linear, 2 sine/cosine	1	<1° at 10 c/s	Diode (10 segment) (a max. of 3 can be incorporated)	2 (approx.)	Not available	Nil	—	—	20-amplifier linear version £1900	March 1961	3	3·3	750 W	Education	Versatile; compact for its computing capacity
	Electronic mark space	0·1	<0·1° at 10 c/s																
⩽25 kΩ	Electronic mark space	0·1	<0·1° at 10 c/s	Can be included as additional item	—	—	Diode (10 segment)	2 (approx.)	Not available	4 diode pairs, 2 diode bridges, 4 relays	—	—	About £7750 fully equipped	Expected to be ready in Oct. 1961	—	20	About 2 kW	General purpose	Expandable in modules up to 168 amplifiers
⩽7·5 kΩ	Servo	0·25	<1° at 10 c/s	Servo type	1	<1° at 10 c/s	Diode (12 segment)	2	<1° at 100 c/s	4 diode limiter-bridges, 4 relay amplifiers	—	—	£10,500	Feb. 1959	12	28	3 kW	Genera purpose	A well proven, reliable, easy-to-use computer
⩽25 kΩ	Electronic mark space	0·1	<0·1° at 10 c/s	Patch panel space for 4 precision servo resolvers	0·25	<1° at 6 c/s	Diode (12 segment)	2	1° at 100 c/s	10 diode bridges; 5 free relays ; 10 relay amplifiers	—	—	About £41,000 according to equipment installed	Expected to be ready early 1962	—	45	About 10 kW	General purpose	Easily expanded
—	Quarter squares	0·5	1° at at 5 kc/s	—	—	—	Diode (18 segment)	—	—	—	—	—	—	Not released	Not released	—	—	—	—

The meaning of a time constant for a linear system is well understood. This data sheet defines a similar concept for non-linear systems

DATA SHEET 24

Definition of an equivalent time constant

by **P. G. MORGAN,** *University of Manchester*

IN ANY PHYSICAL SYSTEM WITH ONE degree of freedom, expressed by the first order linear differential equation

$$\frac{d\theta}{dt} + a\theta = b \qquad (1)$$

where the initial conditions are $\theta = 0$, $t = 0$, and a and b are constants, the solution is

$$\theta = \theta_f\,(1 - \epsilon^{-t/T}) \qquad (2)$$

where θ_f is the final value of θ and equals b/a. $T = 1/a$ and is the *time constant* of the system.

In a non-linear system, where a and b are not constants but functions of θ, there is no such definition of the time constant. In this case, though, θ may build up from zero to a final value θ_f which satisfies the equation

$$b(\theta) = a(\theta) \,.\, \theta$$

It would be convenient therefore, to define an *equivalent time constant* as a measure of the build-up time for this case.

Such an equivalent time constant, $T_{eq(N)}$, has been defined by Nechleba (*1*) with the equation

$$T_{eq(N)} = \frac{1}{\theta_f}\int_0^{\infty}(\theta_f - \theta)\,dt \qquad (3)$$

and it has been extended to the second order linear system with constant damping. $T_{eq(N)}$ is equal to T in equation (2) for the first order linear system. It is necessary to solve the differential equation to obtain $T_{eq(N)}$ by equation (3), but this is not always successful in a non-linear system.

For the first order system, an alternative definition of the equivalent time constant is developed below as a measure of the build-up time.

If the general first order system is expressed by

$$\frac{d\theta}{dt} + a(\theta) \,.\, \theta = b(\theta) \qquad (4)$$

the average of $d\theta/dt$ from $\theta = 0$ to $\theta = \theta_f$ is given by

$$\left(\frac{d\theta}{dt}\right)_{av} = \frac{1}{\theta_f}\int_0^{\theta_f}\frac{d\theta}{dt}\,.\,d\theta$$

$$= \frac{1}{\theta_f}\int_0^{\theta_f}[b(\theta) - a(\theta)\,.\,\theta]\,d\theta \qquad (5)$$

and we may take $b(0)$ as positive, and θ_f as the smallest positive root of $b(\theta) = a(\theta) \,.\, \theta$.

The proposed equivalent time constant, T_{eq} is given by

$$T_{eq} = \frac{\theta_f}{2\left(\dfrac{d\theta}{dt}\right)_{av}} \qquad (6)$$

so that, by this definition, as by Nechleba's definition, $T_{eq} = T$ for equation (2).

To obtain T_{eq} it is not necessary to solve equation (4), as it is in the case of Nechleba's definition, but to calculate the average $(d\theta/dt)_{av}$ from equation (5).

For the first order linear system, equation (1) is shown in Fig. 1. T_{eq} is

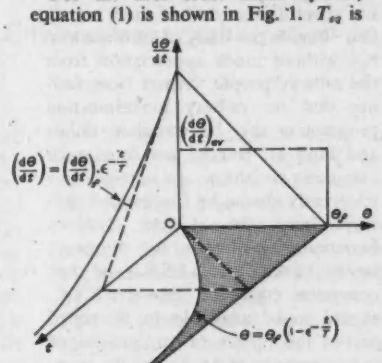


Fig. 1

defined by the slope of the line in the $d\theta/dt$, θ plane, while, in the Nechleba method, $T_{eq(N)}$ is defined by the area shown shaded divided by θ_f.

Examples

As an example, let us consider the system

$$\frac{d\theta}{dt} = b \text{ for } 0 < \theta < \theta_f$$

$$\frac{d\theta}{dt} = 0 \text{ for } \theta = \theta_f$$

In the θ,t plane, the time t_1 for θ to reach its final value θ_f is equal to θ_f/b. From Nechleba's definition given in equation (3)

$$T_{eq(N)} = (1/\theta_f)\,(\theta_f t_1/2) = t_1/2,$$

as shown in Fig. 2.

For the proposed alternative definition given in equation (6)

$$T_{eq} = \theta_f/2b = t_1/2$$

so that in this case, again, $T_{eq} = T_{eq(N)}$ and $\theta_{eq} = \theta_f\,(1 - \epsilon^{-2t/t_1})$

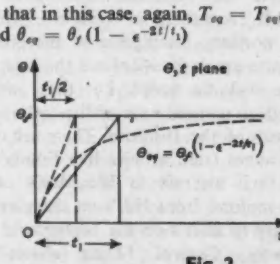
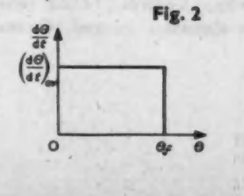


Fig. 2



As a further example, consider

$$a(\theta) = a_1 + a_2\theta$$
$$b(\theta) = b$$

where a_1, a_2 and b are positive constants in the equation (4).

The solution is (Fig. 3)

$$\theta = \theta_f(1 - \epsilon^{-Ft})/(1 + G\epsilon^{-Ft})$$

where

$$\theta_f = [a_1/2a_2]\,[\sqrt{(1 + H)} - 1]$$

$$G = \frac{\sqrt{(1 + H)} - 1}{\sqrt{(1 + H)} + 1}$$

$$F = a_1\sqrt{(1 + H)}$$

and

$$H = 4a_2b/a_1^2$$

Then

$$T_{eq(N)} = \frac{1}{a_1}\,.\,\frac{2}{[\sqrt{(1 + H)} - 1]}\,.\log\frac{2\sqrt{(1 + H)}}{\sqrt{(1 + H)} + 1}$$

by Nechleba's method. On the other hand

$$\left(\frac{d\theta}{dt}\right)_{av} = \tfrac{1}{2}\,.\,a_1\theta_f + \tfrac{1}{3}\,a_2\theta_f^2$$

and thus

$$T_{eq} = \frac{1}{a_1}\,.\,\frac{3}{[1 + 2\sqrt{(1 + H)}]}$$

so that $T_{eq(N)}$ differs from T_{eq} if $H \neq 0$.

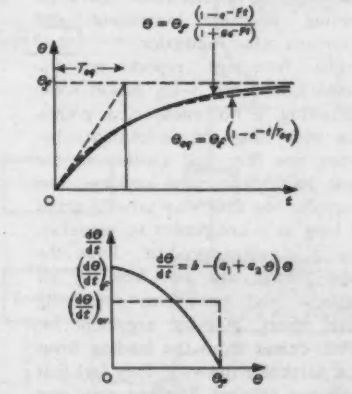


Fig. 3

If $H = 0$ the system is linear and $T_{eq(N)} = T_{eq} = 1/a_1$. It will be noted that T_{eq} is obtained much less laboriously than $T_{eq(N)}$.

The above analysis has dealt with two comparatively simple systems, but it is probable that with more complex equations the alternative definition suggested for T_{eq} may prove to be of more assistance.

Reference

1. Nechleba, Z: *Elektroteknische Zeitschrift* 1953, *74*, p. 98.

Pick-off

by 'UNCONTROLLED'

I SUPPOSE WE ALL RESENT the suggestion that our particular way of doing things may not be as efficient as our competitors', and when 'do-gooding' outsiders suggest that we could manage better if we only tried, we tend to dismiss them as interfering busybodies with no real knowledge of our problems. However, I do feel that the Centre for Interfirm Comparison (I.F.C.), a body set up two years ago by the British Institute of Management in association with the British Productivity Council, is doing a good job. The idea appears to be to establish some sort of figure of merit representing the 'best' in an industry, so that one may compare one's own performance with that best. I gather that I.F.C. is a reputable organization set up to handle the confidential pooling of management data, and that at the moment they are working with the electrical, light engineering, scientific instrument, and seventeen other industries.

The four-page report on the Centre's first two years makes some interesting, if not unexpected, points. The wide range of performance between one firm and another in the same industry is quite striking. For example, one firm may take 2½ times as long as a competitor to manufacture a standard product. Even the 'best' firms are not best in all respects, and can learn something from others. Another argument for I.F.C. comes from the leading firms in a particular industry; they feel that their less efficient brethren may give the entire industry a bad name.

AUTOMATION, to my mind, includes such things as introducing automatic coupling for railway wagons—some readers will no doubt contradict me and say that this would be mere mechanization. Whatever else it might be, it surely would class as 'modernization', and British Railways are reputedly modernizing. Yet, according to William Larke in a recent issue of *Steel Review*, there has been some astonishing resistance to reform. Apparently the steel industry has spent a great deal of time, money and effort in the study of such matters, but without much appreciation from the railway people. 'Apart from feeling that no railway modernization programme can be complete unless and until all wagons are fitted with automatic couplings—an opinion now apparently shared by Continental railways and the United Nations Economic Committee for Europe', writes Larke, the B.I.S.F.'s *ad hoc* committee considers 'that the B.T.C. should make available to interested parties the results of any studies of the economics of an automatic coupling'. That seems fair enough to me. Of course this contribution to modernization would cost a lot, but as Larke remarks: 'The industry may . . . have to face up to an increase in operating costs if the safety of its workers is to be assured'.

THE SOVIETS made deep studies of foreign literature in their early efforts towards industrialization, and they continue to keep close watch on all technical doings in the west. To some extent this is an indication of the leeway they know they have still to make up, but my guess is that they will go on searching us out if and when they overtake.

I have just been thumbing through the packet of abstracts from *Control* that we recently received from the Institute of Scientific Information, U.S.S.R. Academy of Sciences. The only portions intelligible to me (the abstracts are in Russian) are the references in Latin script, but these are enough to convince me of the catholic interests of the Institute. Their selection ranges from articles like Foody's on v.t.o.l. aircraft to Wearden's on servo-motors, from Hill's on the glass industry to Beer's on the 'cybernetic' company. *Control* 'Data sheets', 'Ideas applied . . .' and 'Control in action' are other features liberally drawn upon. Of course, the existence of a good abstracting service does not necessarily imply that good use is made of it, but I should imagine that the utilization is pretty high in the U.S.S.R.

LAST MONTH'S N.P.L. conference on machine translation* reminded me of an essay by Gerard Fay in *The Guardian*. His subject was simplified spelling, and one of his passages needs to be drawn to the attention of forward-looking computer-designers. 'In abowt as short a tiem as it wood take Mr Marpulls to bild a motrway from Lan's End to John o' Grotes', promised Fay, 'I am going to perfekt my desimal letter-numeral sistem which will rejuice the three Rs to one. Breefly the idea is that the alfabet will contain ten symbols. The same cymbals will serve as figgers so that reeding, riting, and rithmetic will bikom a single ntiti. Simpl, izntit?' Of course! I hope that the N.P.L. will be on to this.

LAST JUNE I remarked on the advancement of π to 10,000 places in a thirteen-hour computation by a British machine. I now hear from I.B.M. that they got this far back in 1958, and that their 7090 computer in London has just pushed π on to 20,000 places in a matter of 39 minutes. At least, I *think* they mean π; their note actually says that '22 over 7 was calculated, but I presume that this is their tactful way of jogging a mere journalist's memory associations. I.B.M. add that the same program can, without modification, stretch the value for π (or do they really mean 22/7?) to 100,000 places. The 7090 has also computed *e to* 20,000 places in 14min 24s, and could carry this on to 142,000 places without change in program.

You will no doubt share my delight that the written computer output is available on request.

AUTOMATION and a.d.p. could speed the decadence of our society, if we weren't careful. The following tale (true, I'm told), signposts the slippery path only too clearly. After accumulating goods in a large store, a shopper went to face the consequences at the cash desk. The girl on the other side, looking very sweet, passed the bill over and said: 'Please could you do it for me—the adding machine's broken down.'

* Reported by Dr Andrew Booth on p. 103 this month.—EDITOR

CONTROL IN ACTION

Temperature control for radar display system

Environment stabilization permits use of transistor techniques

RADAR DISPLAY AND DATA-HANDLING systems have become massive complexes of equipment during recent years, mainly owing to the demands of the military although civil air traffic control requirements are also growing extremely rapidly. A system of medium size may employ some 10,000 thermionic valves and, apart from such physical difficulties as those connected with housing the system (possibly in an underground operations room), the vast amount of power it consumes and the air-conditioning problem, experience proves that, on average, one valve fails every hour of operation.

This problem of reliability led Decca Radar Ltd to consider the use of transistors instead of valves. Unfortunately, the transistor, although offering great advantages in terms of reliability, low power consumption and small size, is extremely sensitive to temperature, the 'drift' with temperature normally precluding their use in high-performance equipment.

In order to overcome this thermal instability of the transistor, Decca Radar have adopted 'environment stabilization' for their new TDS mk V radar display and data-handling system. This is a fully transistorized equipment understood to be capable of handling a wide range of display needs, whether simple, as from a single radar, or complex and of the type employing digital computers with multiple radar and other data inputs.

The technique of environment stabilization will be apparent from a study of the simplified diagram, Fig. 1. All transistors and components are contained in so-called 'cold plates' (see Fig. 2), each cold plate holding up to 21 printed-circuit boards. The equipment consists of three cold plates per cabinet, the cabinets being themselves in groups of three, a fourth cabinet acting as a power and coolant cabinet (Figs. 3 and 4).

Each cold plate housing the printed-circuit boards incorporates ducts carrying a coolant liquid and is surrounded by an electric heating 'blanket'. The flow of coolant liquid to the ducts, or of power to the blanket, is thermostatically controlled in the manner of Fig. 1 so that the surfaces of the cold plate are maintained at the required temperature (say 20–25°C) to an accuracy of ±0·25 degC. Each printed-circuit board is mounted in a metal surround which carries the transistors in metal clips and, as the surround is in good thermal contact with the cold plate, the transistors are thus held at a stable temperature.

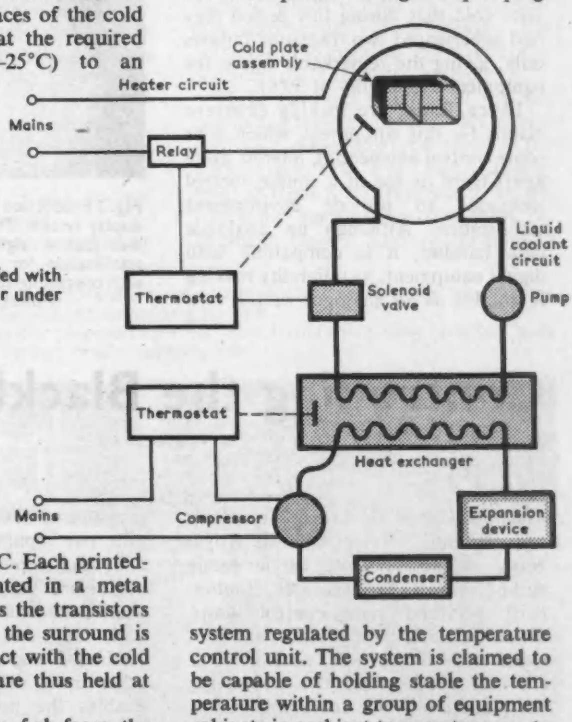


Fig. 1 The 'cold plate' is fed with coolant and heating power under thermostat control

The cold plates are fed from the power and coolant cabinet (Fig. 4), the upper part of which supplies stabilized h.t. to printed-circuit boards in three equipment cabinets—local h.t. stabilizers are also fitted to individual cold plates.

The lower part of the cabinet contains a heat exchanger and refrigerator system. Duplicate industrial refrigerator units supply coolant to the heat exchanger tank, each refrigerator working for part of the duty cycle. A secondary cooling coil in the heat exchanger tank provides coolant to the cold plates through a pumping system regulated by the temperature control unit. The system is claimed to be capable of holding stable the temperature within a group of equipment cabinets in ambient temperatures up to 45°C.

During a recent visit to Decca Radar's display and data-handling laboratories, *Control* saw both a pro-

Fig. 2 The upper unit is the cold plate which contains 21 printed-circuit boards. The transistors are fitted in the metal surround around the boards

duction version of the TDS mk V and an experimental version of the equipment which, at the time of our visit, had been running for 10,259 hours. We were told that during this period they had experienced two transistor failures only, giving the remarkable figure for equipment availability of 99·8%.

Decca Radar are making extensive claims for this equipment, which is of some control engineering interest quite apart from its use of a simple control technique to provide environment stabilization. Although an analogue data handler, it is compatible with digital equipment, its reliability making it suitable as an analogue output to a high performance digital data processor.

It is, of course, with digital systems that the future of air traffic control appears to lie, for the digital computer will be essential in large data-handling systems. A large-scale analogue arrangement capable of handling great amounts of data of a differing nature, and accepting these from many data inputs, would not only be difficult and expensive to engineer, but would not be able to meet the high-speed and high-reliability requirements of an on-line, real-time data-handling system.

Fig. 3 Production version of the transistored display system. The power and coolant cabinet (below, right) provides environment stabilization for three electronic cabinets each containing three cold plates holding 21 transistor-circuit boards

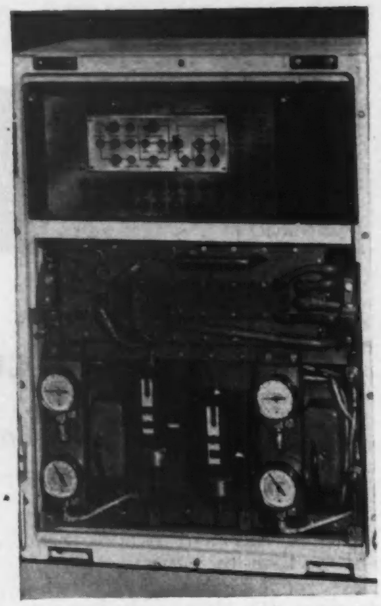


Fig. 4 The power and coolant cabinet contains duplicate refrigerator units and a heat exchanger from which coolant is fed to the cold plates

The use of transistors has not only given the equipment a high standard of reliability but also made it inherently compact. For example, it is understood that in a typical system employing a digital computer in conjunction with the new TDS mk V display, about 34ft^3 of electronic and environment stabilization equipment would suffice to drive sixteen viewing units, whereas conventional thermionic valve equipment might require some 300ft^3 of drive equipment located in approximately twenty separate units, each of which would have to be interconnected and tested on site.

Controlling the Blackburn Buccaneer

Auto-control of powered flying controls

The Blackburn Buccaneer, which is soon to enter service with the Royal Navy as its standard carrier-borne strike aircraft, incorporates Boulton Paul powered flying-control units. Three basically similar units are provided for the power actuation of ailerons, rudder and the all-moving tail plane, each unit consisting of two separate hydraulic rams arranged in tandem, with a rotary valve controlling the supply of fluid to each ram.

The aircraft's hydraulic system provides the supply to the units at a pressure of 3300 lbf/in^2. There are, in fact, two separate systems, one fed by a hydraulic pump driven by the port engine and supplying fluid to the autostabilizer actuator and one ram of each unit, and one powered by the starboard engine and supplying the other ram. This dual arrangement enables the power control units to continue functioning in the event of a hydraulic pump or one engine failing. Performance would be reduced, but adequate control of the aircraft maintained.

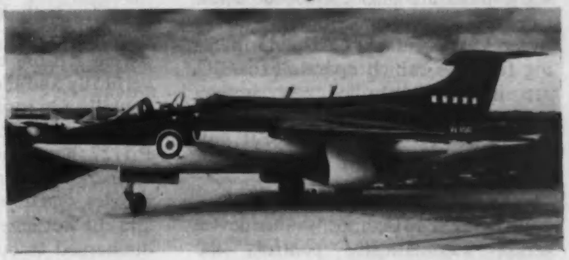
Manual, semi-automatic, or fully automatic operation of the aircraft's flying controls are provided by the Boulton Paul system. Under manual control, the pilot provides a mechanical input to the units *via* a series of push-pull rods and cables which transmit his commands to the input linkage of the units. For semi-automatic operation (i.e. mechanical input plus autostabilization), the pilot controls his aircraft manually, as before, but in addition short-term correction signals are fed into the actuator of the

control unit by electrically operated autostabilizer mechanisms.

In the fully automatic mode, that is using both autostabilizer and (Elliott) autopilot, the pilot is divorced from the control of his aircraft, the unit being under direct autopilot authority.

An autopilot/autostabilizer actuator is an integral part of the unit, which has two differentials in its mechanical linkage. When the aircraft is piloted manually, the hydraulic actuator is locked and one differential is inactive. On selecting the autostabilizer, correction signals are fed into the hydraulic actuator system and are added to the pilot's signal through the second differential. Under these autostabilized conditions the pilot's control is not moved by the autostabilizer and, because of the mechanical feedback from the power control unit, autostabilizer runaway is limited in proportion to the stroke of the actuator.

When the autopilot is engaged, long-term signals are also fed into the hydraulic actuator system. The input lever of the differential assembly is locked and the pilot's control is driven by the hydraulic-ram output, while the unit is under the direct control of the actuator. The servo loop back to the autopilot is closed electrically using a pick-off on the ram.



The Royal Navy's Buccaneer has Boulton Paul powered flying controls

A given stroke of the actuator produces a rate of movement of the ram and, although the travel of the control surface is not restricted, the effects of runaway are limited by the stroke of the actuator. As the pilot's controls always follow the movement of the control surfaces, he can regain control at any time by disengaging the autopilot. This will automatically free the differential pivot system, so that the pilot can feed in a mechanical input.

According to Boulton Paul, many hundreds of flying hours have been completed using this system with extremely satisfactory results.

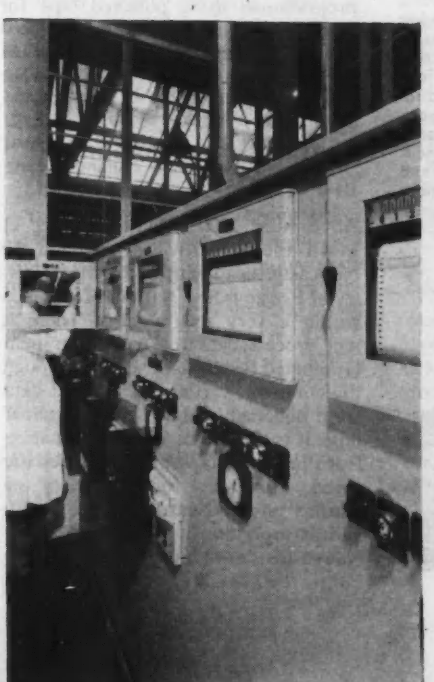
Furnace control at Automotive Products

Seven heat-treatment furnaces instrumented

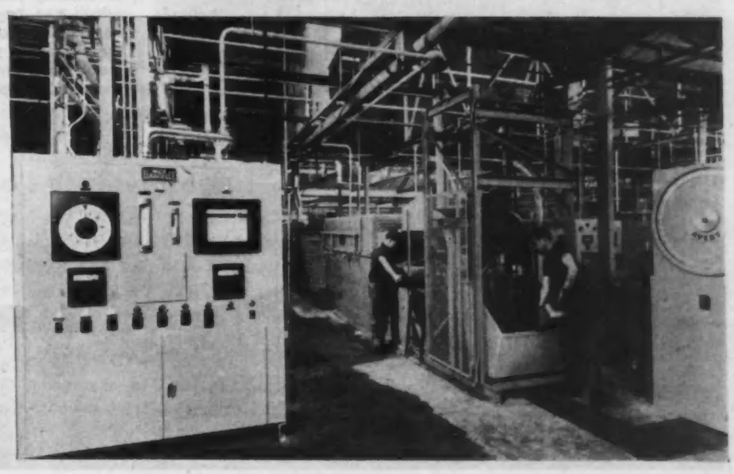
At the Leamington factory of Automotive Products, seven new heat-treatment furnaces have been installed, and these are instrumented and controlled by Honeywell Controls' equipment. A Wild Barfield electrically-heated shaker-hearth furnace is operated under temperature control, a circular-scale instrument controlling 'zone 1' at the loading end of the furnace, and a continuous strip-chart instrument recording and controlling the temperature of the components in 'zone 2' before they are dropped into the oil-quench. The admission of the endothermic atmosphere is controlled by built-in safety devices within the instrument, so that gas cannot be fed to the furnace unless the latter is at the proper temperature; and both load and furnace are protected against overheating by Protect-O-Vane units. It is reported that components treated in this furnace remain as 'bright' as they were before heat-treatment.

The other furnaces were supplied by British Furnaces Ltd. Both zones of a gas-fired continuous cast-link-conveyor furnace, which is used for oil-quenching automobile clutch-forgings, are temperature-controlled by a continuous strip-chart recorder-controller.

Three gas-fired furnaces of the air-circulating type are used for tempering, and two other gas-fired models for normalizing, all five being instrumented from a separate panel. In the tempering furnaces, a two-point instrument records and proportionally



Left: Five Honeywell strip-chart recorder-controllers regulate the temperature conditions in tempering and normalizing furnaces
Below: A circular-chart recorder controls 'zone 1' and a strip-chart recorder 'zone 2' of this Wild Barfield shaker-hearth furnace



controls the temperature of the air, both before admission to the load and immediately after leaving the load. When these temperatures are equal, the process commences under the control of timers, so giving the correct time-temperature cycle for each load. Automatic Protectoglow devices protect against explosion, and Protect-O-Vane units are also employed. These furnaces operate at temperatures between 550°C and 650°C. The normalizing furnaces, which operate at 900°C, are similarly controlled.

Auto-control of vertical flight

The Short SC.1 v.t.o.l. aircraft is now fitted with a lift-compensating device which automatically controls the machine's vertical position in relation to the selected flight path. This lift compensator is an electrohydraulic controller which automatically reduces to zero any vertical accelerations externally imposed on the aircraft by gusts during the transition period—i.e. when changing from vertical to horizontal flight. An accelerometer is used to detect the gusts, and its output is fed to a transistor amplifier which drives a servo-motor. The latter controls the fuel supply to the engines and so corrects for the externally imposed accelerations.

A triplex autostabilizer is being used to provide the aircraft with an attitude control in pitch and roll, irrespective of external moments, as well as artificial stability at low and zero forward speeds.

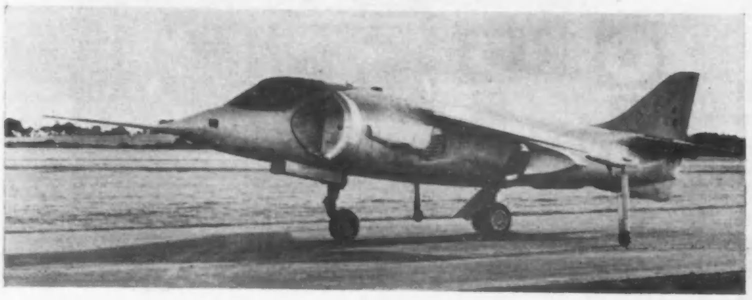
Rotating P.1127's jet-nozzles

The Hawker P.1127 v.t.o.l. aircraft is powered by a single Bristol Siddeley Pegasus turbo-fan jet engine which provides both lift and thrust—unlike the Short SC.1 which has five Rolls-Royce RB.108 engines, four mounted vertically and the fifth exhausting horizontally for forward flight.

The single Pegasus engine in the P.1127 has four jet-nozzles, the fan discharging through two forward nozzles, one on each side of the engine, and the hot jet exhaust being similarly discharged through two nozzles at the rear. For vertical take-off and landing, all four nozzles are pointed downwards, and during the transition to forward flight the nozzles are rotated rearwards, being directed fully aft for horizontal flight.

Plessey have produced a pneumatic actuation and control system which is understood to provide the power for rotating the jet nozzles to any desired position with great accuracy. A high response rate is claimed, together with the ability to withstand wide temperature changes, and freedom from aerodynamic creep. This rotating-nozzle controller is entirely self-contained and is powered by bleed-air from the Pegasus engine it controls.

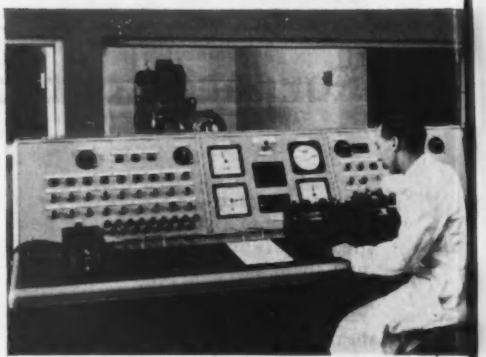
Left: The Short SC.1 v.t.o.l. aircraft in transition from hovering to forward flight at R.A.E., Bedford
Below: The Hawker P.1127 v.t.o.l. machine employs 'vectored thrust', the four jet-nozzles (two of which can be seen here) being rotated by Plessey's pneumatic actuation and control equipment



Auto-testing aircraft systems

A new Plessey laboratory at Romford, Essex, is now testing and developing aircraft generation systems. The initial installation, which is at present proving a 160kVA four-generator system for the Vickers VC.10, is capable of handling four parallel channels of generating equipment of up to 120kVA load per channel, under simulated environmental conditions. The generator-drives have a speed range in excess of 3 : 1 with controlled acceleration up to 1200 rev/min/s, and a capacity of 200h.p. each. Three-phase loading, both resistive and reactive, is variable between zero and 150kVA per channel.

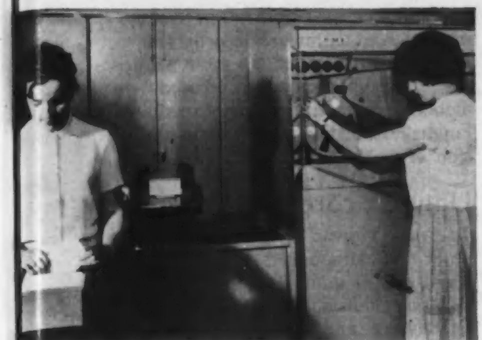
To prove the equipment, Plessey have installed what they consider to be the most advanced system of automatic testing for generation electronic-control equipment in the world. Testing is carried out by point-to-point fault-location consoles, which can be programmed using punched tape for automatic continuity and wiring verification on any type of control or ancillary unit.



Testing a 40kVA generating system at Plessey's new Romford laboratory

Pensions-data handling in Newcastle

An Emidec 2400 digital computer of E.M.I. Electronics will be in use at the Newcastle headquarters of the Ministry of Pensions and National Insurance within a very few months. There it will process data for the government Graduated Penesion Scheme. Although the computer can accept original data from punched cards or punched-paper tape, it can read the same information from magnetic tape at forty times the speed. However, for a variety of reasons punched cards must be used, and at the moment some 250 girls in Newcastle are busily transferring



The E.M.I. tape-card converter

selected personal data on to punched cards. The current rate of punching exceeds 500,000 cards a week.

In order to overcome this problem of feeding the Emidec 2400 at a rate fast enough to exploit its potentialities, E.M.I. have developed a card-tape converter which transfers information from the punched cards to magnetic tape. Basically this consists of a photo-electric card reader operating at about 320 cards/min, which extracts the intelligence from the cards and stores the data from three cards at a time in a ferrite-core store, before recording it on magnetic tape.

Essentially the computer's task will be to process the details of contributions to the Graduated Pension Scheme. Before this can be done, a magnetic-tape file containing the personal details of 26,000,000 persons has to be produced. At present the tape-card converter is being used to tape individual records at about 1,000,000 a week, and the file should be complete by the end of the year.

The card-tape converter will also carry out the reverse process. The computer must produce data in punched-card form, a task which if carried out directly would require a great deal of computing time. However, the card-tape converter will be used to accept a magnetic-tape output from the computer, and translate this on to punched cards.

Control understands that the Pensions duty requires over sixty programs to be written for the computer, and that seven teams of programmers are now at work in Newcastle. Four programs have been completed and tested on a prototype machine at E.M.I. Electronics, Hayes, and a further twenty programs are now undergoing test.

Automatic meteorological station

An automatic unmanned weather station of the U.S. Weather Bureau is now in operation on Axel Heiberg Island in the most northerly part of Canada. Electric power for the station's transmission is provided by an atomic power generator. This consists of about a pound of strontium-90, heat from its radioactive decay causing a thermoelectric assembly to produce about 5W. This is used to charge the batteries powering the transmitters.

An anemometer, thermometer and barometer, measure wind direction and speed, temperature and barometric pressure, and feed these readings into a data-processing and storage system for radio-transmission to manned weather stations every three hours.

According to American reports the station was in operation on 22 August, and is expected to operate without attention for about two years.

Hopper-level control at Glenvilles'

A simple 'high' and 'low' level controller installed at the Greenwich plant of Glenvilles Ltd by Electronic Machine Co., is understood to have smoothed considerably the continuous packaging of custard powder. The powdered product is taken by motor-driven elevator directly from the mixers and dropped into feed hoppers situated immediately over the filling machines. Two level probes are installed within the hoppers, one at the top and the other near the bottom, and when the custard powder reaches the top probe a relay operates to halt the elevator drive. As the custard powder is fed from a particular hopper into the filling machines, the level within the hopper falls until it reaches the lower probe. This operates the relay again to start the elevator-drive motor and refill the hopper until the process is halted again on the level reaching the top probe. This on–off cycle continues during the entire production run.

It is reported that this simple system of level control has eliminated overflowing of the hoppers and wastage of the product.

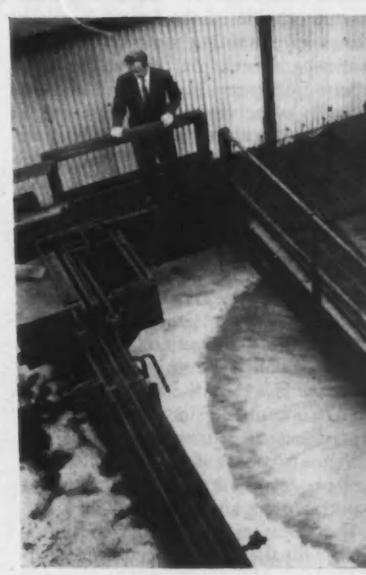
Esso's data recorders

Many Esso service stations are now using data recorders by Addressograph-Multigraph to assist in accounting procedures. Each driver of a commercial vehicle within the Esso scheme has a credit card of plastics material, which he hands to the garage attendent when receiving his fuel. This is inserted into a data recorder and the necessary information (name and address, account number and zone of the station) is imprinted on to a punched-card set, the number of gallons, the vehicle's registration number, and the date being added by hand. It is understood that the use of these plastics credit cards in conjunction with a data recorder is saving a great deal of labour. Possibly more important, however, is that the punched cards produced in this manner provide 'source data' for an I.B.M. 1401 computer.

Esso, incidentally, are setting up a central computer installation in their new building in Victoria Street, London. The installation will include two I.B.M. 1401's, and an I.B.M. 7070.

Notching-up effluent

The Rivers (Prevention of Pollution) Act, 1961, came into force on 27 September and this lays down requirements relating to effluent disposal. The disposer has to state the nature and composition of the effluent, its maximum temperature, the maximum daily quantity, and the maximum rate of discharge. Walker Crosweller's Arkon instrument division recommend the well known V-notch weir or Venturi flume methods of flow measurement, together with a liquid flow recorder, for measuring, recording and integrating the volume or rate of discharge of effluent. Here, the vee-notch weir method is in use at the Gas Council's experimental effluent-processing plant at Southall gas works, there being two alternative oxygenating tanks for the liquor. The two vee-notch weir tanks are on the extreme left—in practice both tanks would be covered to avoid wind ripples on the surface of the liquid leading to poor measurement.



NEWS ROUND-UP

from the world of control

PROFESSIONAL

Brit. Comp. Soc.'s A.G.M.

The British Computer Society, which presented its 1960–61 report to the Annual General Meeting on 26 September, has had another successful year, with an improved financial position and an increase in membership to well over 2200. Eleven meetings were held in London during the year: these were well attended and, perhaps more significant than the numbers present, had satisfactory question and discussion sessions.

There were fewer B.C.S. study groups than in previous years, but those in existence were exceedingly active. A detailed examination of one version of Cobol has already been carried out, another group is surveying input/output requirements, while a third is examining the fundamentals of business applications for the purpose of preparing a source language.

The various Committees of Council had a busy year. The Education Committee considered the Society's role in developing training methods for computer personnel. At present there are about 5000 persons employed as computer supervisors, programmers, coders, operators, junior technicians and maintenance engineers: by 1965 nearly 20,000 will be needed.

The Scientific Programming Committee held meetings at which Algol and other recently developed languages and programming techniques were discussed. It appears that interest is spreading in list processing, symbol manipulation and general schemes for compiler construction.

Active work by the Data Transmission Committee started during the year. They are attempting to establish both users' needs and potential facilities in co-operation with computer manufacturers and the Post Office.

The Glossary Committee continued work with the British Standards Institution on its proposed glossary, which is now nearing completion. The B.C.S. is responsible to the Provisional International Computation Centre, for the English aspect of a multilingual glossary. The Society is a member of the International Federation of Information Processing Societies which is now collaborating with the P.I.C.C. on the multilingual glossary. An I.F.I.P.S. committee has been set up for this purpose with G.C. Tootill (the chairman of the B.C.S. Committee) as chairman.

A committee on Document Handling and Character Recognition has been formed recently and two meetings held.

The annual prizes foı published papers were awarded at the meeting to Dr H. H. Rosenbrock (C.J.B.) for *An automatic method of finding the greatest or least value of a function*, and to A. J. Platt (Pilkington Bros.) for *The experience of applying a commercial computer in a British organization.*

D. W. Hooper (Chief Organizing Accountant, N.C.B.) is now the Society's President in succession to Dr F. Yates, F.R.S., who becomes a Vice-president as do H. W. Gearing (Metal Box) and A. Geary (Northampton C.A.T.). These three join the existing Vice-presidents, Dr M. V. Wilkes, F.R.S., a Past President (see also page 86), R. L. Michaelson and E. E. Boyles.

The Society's third conference is to be held in Cardiff in September 1962.

DATA PROCESSING

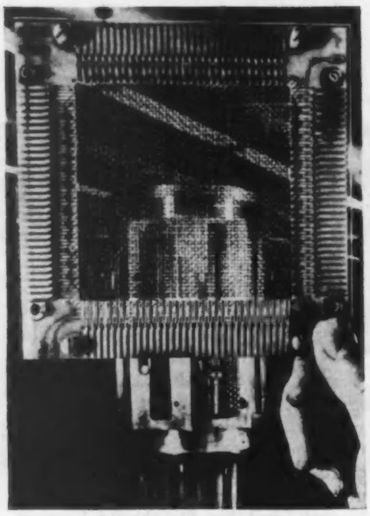
61 1301's ordered

At a recent press conference I.C.T. announced that 61 orders had been received for their new 1301 e.d.p. system, representing a total capital value of approximately £6·5m. More than a third of these orders are said to come from overseas.

An extensive library of mathematical and commercial programs is available to users of the 1301. Automatic programming is based on Cobol (common business orientated language) and on an I.C.T. modification of Cobol known as 'rapid write'.

Univac's core/drum stores

The new Univac Solid State II computer just announced by Remington Rand is a medium-scale system which is rather unusual in that it has both ferrite-core and fast drum memory systems. The machine has 14,080 digits of core storage and between 28,600 and 96,800 digits of drum memory. Information stored in the core memory can be assessed at the rate of 1·5μs/digit, and a variable multi-word transfer feature allows data to be moved between drum and core storage in the same access time per digit.



Core memory plane for the new Univac Solid State II computer

R.A.E.'s data logger

A transistorized data-logging system capable of reading information from 100 transducers a second by a sequential scanning process, is being developed by Mullard Equipment for use at R.A.E., Farnborough. There it will examine the behaviour of models in a high-speed wind tunnel.

The system performs five basic functions: scanning, amplification, digitization, coding and presentation. A number of scans are made during a typical test run, which may last for just a few seconds or as long as a minute. The information gathered from the various transducers is first

amplified and digitized, and then recorded on magnetic tape in a five-unit code. After the run, the results can be recorded immediately by a teleprinter, or the magnetic tape used as the input medium to a computer.

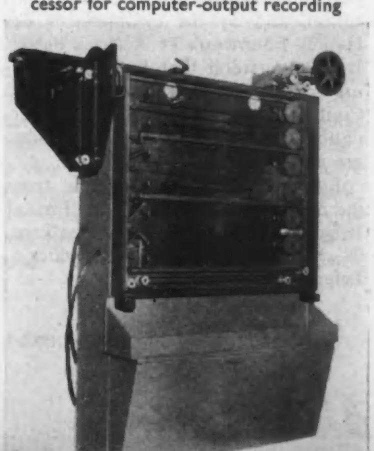
Xeronic printer in production

The first production model of the Rank Xeronic output printer has been completed and will work with an Emidec 2400 computer which is to be delivered to the Ministry of Pensions and National Insurance later this year. Other Xeronics scheduled for delivery this year are destined for the R.A.F. Central Accounting Unit (working with an A.E.I. 1010 computer) and for Commercial Union Assurance (English Electric KDP 10 computer).

The Xeronic differs from conventional output printers in having no high-speed reciprocating parts. The computer output is converted to symbolic representation on cathode-ray tube screens, which are 'photographed' by xerography—a basically electrical process—at speeds up to 4700 characters/s. A feature of this printer which is claimed to be unique is its ability to print forms at the same time as computed data, avoiding the need for stocks of ready-printed forms.

Above: Rank Xeronic computer-output printer

Below: Kelvin Hughes rapid-access film processor for computer-output recording



Photographic printing

Also interested in 'non-mechanical' forms of output device are Kelvin Hughes, who are developing their type RP.1 rapid-access film processor for this purpose. Characters are again first displayed on a cathode-ray tube, and are reproduced by a more conventional (though very high speed) photographic process.

FUEL

Telemetering gas

Plessey are to install a remote control and telemetering installation for the Norwich Division of the Eastern Gas Board. The system, which has its control centre at Norwich, will cover eight gasholder sites in the Division—Lowestoft, Southwold, Beccles, Diss, Halesworth, Harleston, Bungay and Loddon—and will be capable of extension to a further six out-stations.

The installation will display at the Norwich control room the following functions from each of the out-stations: gasholder stock, medium pressure and district pressure, all with 'high' and 'low' alarm indicators. Remote control is provided for booster on/off, volumetric governor, and anti-freeze on/off.

Transistor circuits are used throughout the coding and data transmission equipment. Information is transmitted in the form of digital code signals over Post Office lines, although the Plessey system is also suitable for use with a radio link or power-line carrier installation.

Installation is expected to start in February 1962 and the complete system should be in operation by June of the same year.

BUSINESS

Pneumatics and Europe

At a recent meeting in Duisburg, West Germany, it was decided to form a body to allow the economic problems connected with oil hydraulics and pneumatics to be treated by a communal economic commission. This organization is to be known as the European Technical Pneumatic Controls Commisssion. A comprehensive working programme was established. This covers the definition of terms, terminology, drawing symbols, standardization of tube fittings and threads, preparation of working and maintenance manuals, standardization of cylinders, and the standardization of valves. Germany, Sweden, the Netherlands, France, Belgium and Britain were represented at the meeting. The British delegate was R. W. W. Taylor, Managing Director of Lang Pneumatic Ltd, who is to become Vice-chairman of the Commission.

Plessey's hydrostatic transmission system

A truck equipped with Güldner hydrostatic transmission is being demonstrated at Plessey's Swindon works. Plessey are to supply and eventually manufacture this transmission system, which has already been in use for some years in a number of continental countries. As used on the truck illustrated, the transmission comprises a variable-capacity positive-displacement pump feeding individual fixed-capacity positive-displacement motors driving each of the rear wheels. Control in this case is by two pedals which vary the pump stroke, one pedal giving forward motion and the other reverse. If required the pump may be fitted with a control unit giving a constant horsepower output, ensuring most efficient use of the prime mover without overloading the hydraulic equipment.

Güldner Hydrocar demonstrated by Plessey at Swindon

R and D

Satellite components

Work on the development and application of components for space vehicles is being carried out by the Plessey Co. They report their activities as falling broadly into three streams: miniaturization and microminiaturization; *g*-resistant characteristics; capability to operate at high temperatures. They are also developing such new components as the solar cell.

As far as miniaturization and micro-

HELICAL AERIALS TO TRACK SPINNING MISSILES Five aerials which, with their associated synchronization equipment, are being supplied to the War Office's Trials Establishment, Guided Weapons, Royal Artillery, on the coast of Anglesey, by Cossor Radar and Electronics. The aerials are slaved to a bearing and elevation read-out from a master tracking equipment. Two aerials are for use with dual-purpose 100 Mc/s transmitters, one on 'stand by' and the other transmitting signals which interrogate equipment within the missile. The reply is received in the 200 M/cs region by a third aerial. The remaining two aerials operate in the 400 M/cs region, and receive other telemetered data from the missiles in flight. These helical aerials are circularly polarized in order to minimize the unwanted signal modulation which arises from a missile's spinning in flight.

miniaturization are concerned, they are working on (a) component substrate systems—producing a range of components in a flat form of standard dimensions; (b) the deposited circuit in which components are formed by chemical deposition or evaporation; (c) solid-state circuitry—the homogeneity of a material, usually silicon, is changed so that individual components with the required parameters are formed and physically arranged so that they are resistively or capacitively coupled in the required manner.

Among the *g*-resistant components are potted matrix units for aircraft computer systems and sub-miniature skeleton potentiometers for g.w. applications. Work on components for use at high temperatures is going on continuously and transformers capable of working at 500°C have already been produced.

The work on solar cells is concerned with silicon photovoltaic types, and these have the high conversion efficiency of 12·5% at present.

Specially designed equipment is being used by Plessey to ensure the reliability of individual components under the conditions of high acceleration which may occur during the launching of a satellite. One such reliability test is illustrated.

Multi-connectors undergoing a vibration endurance test at Plessey, Ilford

TRANSPORT

Bus tickets taped

A bus ticket issuing machine has been developed by Creed & Co. which, besides producing the actual ticket, code-punches details of the transactions in paper tape. This tape is subsequently fed into an analyser which automatically produces a sterling total of the day's takings, together with other data of statistical interest. The punched tape is produced as a by-product of the normal ticket issuing operation. Each ticket bears five fare values, and combinations of these are punched out so that the sum of the remaining figures represents the fare paid. As the ticket itself is punched, its value is simultaneously recorded in paper tape in the form of punched holes.

At the end of the day the tape is fed into an automatic analyser comprising a tape-reading device, coupled to an electromechanical arithmetic unit. A series of counters progressively indicate the sterling total, the total number of passengers carried, and the individual totals of each value of ticket issued.

METALS

Auto-control seminar

The Institute Belge de Régulation et d'Automatisme (I.B.R.A.) is organizing an international seminar on automatic control in the iron and steel industry, which will take place in the Brussels Palais des Congrès from 19–23 February 1962. The seminar is sponsored by the Communauté Européenne du Charbon et de l'Acier (C.E.C.A.), by the Belgian Ministries of Economic Affairs and National Education, and by the Groupement des Hautes-Fourneaux et Aciéries belges. It is understood that both the International Federation for Automatic Control (Ifac) and Association Internationale pour le Calcul Analogique are also sponsoring the seminar.

Further details are available from the Secrétariat Permanent de l'Institut Belge de Régulation et d'Automatisme, 98 chaussée de Charleroi, Bruxelles 6, Belgium.

NEWS BRIEFS

Hydraulic control valves by Hydraulic Units Specialties Co., U.S.A., are to be manufactured in Britain by Rubery Owen & Co. and marketed by Dowty Hydraulic Units Ltd under the name Dowty-Husco.

Davy–A.E.I. Automation Ltd, a company jointly owned by A.E.I. and Davy-Ashmore, has been formed to take over the interests of the A.E.I./Davy-United Steelworks Automation Unit.

Russian tire plant: Simon Handling Engineers have received a £1·8m contract for equipment for the handling, storing and automatic-weighing of raw materials in a new tire factory to be built at Voljsk, near Stalingrad.

Introduction to digital computers: a course of ten evening lectures begins on 13 October at Hatfield College of Technology, Hatfield, Herts. Telephone, Hatfield 4421.

Mervyn Instruments have joined Gulton Industries (G.B.) Ltd the subsidiary of Gulton Industries Inc., U.S.A. West Instrument also joined Gulton recently.

Brooks Instrument Ltd, Cross Lane, Marple, Cheshire, has been formed with David Y. Smith as Managing Director. Brooks Instrument Inc., U.S.A., have already set up a European Head Office at Fribourg, Switzerland, the European Manufacturing Plant at Veenendaal, Holland, and Brooks Instrument (Vertriebs) G.m.b.H., Ulm, Germany.

Fairchild Semiconductor products are to be manufactured and marketed in Europe by Societa Generale Semiconduttori of Milan, a company in which Fairchild hold a one-third interest.

Communications satellite project TSX: the Post Office is to participate in tests of the U.S. N.A.S.A.—A.T. & T. 'active' satellite which is to be launched in early 1962.

Instrumentation for Trawsfynydd nuclear power station to the value of £32,000 has been ordered by Atomic Power Construction Ltd from George Kent Ltd.

Smith SEP.2 autopilots to the value of £190,000 have been ordered for Nord Noratlas freighter aircraft of the German Air Force. This is a repeat order. One Noratlas is being fitted with the R.A.E. Autoland system which is to be tested in Germany.

WESTCOTT
professing automation

PEOPLE IN CONTROL

by Staffman

I am delighted to hear of Dr J. H. Westcott's Professorship in Electrical Engineering at Imperial College. He has been Reader in Automatic Control there since 1957, and his new title shows the academic world's respect for Westcott himself, although I would have liked his Professorship to have included some reference to automatic control. Professor Westcott is, of course, *Control*'s consultant on systems and a frequent contributor—his latest appears on page 108 of this issue.

You may recall Winston Electronics becoming a subsidiary of the Dynamics Corporation of America. Now I hear that **F. Winston Reynolds**, the founder of the British firm, has relinquished the positions of Chairman and Managing Director. **W. Allen Bridges**, who is the Director of European Operations for Dynamics, takes over those duties. I gather that Reynolds is to devote the whole of his time to exploiting the company's loudspeaking telephones, although he remains on the Winston board along with Bridges, **R. F. Laurence** and **J. Samuels**.

R. T. Gladwell has been appointed Industry Group Manager for Aircraft-Marine Products (G.B.) Ltd., who are probably best known for their solder-less wiring devices and systems including patchcord programming units. Gladwell joined A.M.P. six years ago from English Electric Aviation at Luton and Stevenage, where he worked on g.w. projects. Last year he became A.M.P.'s Electronics Industry Manager. I am told that Gladwell's new appointment is part of the firm's expansion programme—their new factory at Port Glasgow was officially opened on September 25.

The recently formed company, the Severn Instrument Co. Ltd, Tewkesbury, appears to stem very largely from the Audco Annin control valve concern. A Director and Manager is **K. H. Lloyd**, who was the Audco Annin Engineering Manager, and now I hear that **J. D. Holland** who was Works Manager with Gloucester Controls (also Audco Annin) has joined Severn as a Director. The new firm was set up to provide a sales agency for control equipment in South Wales and south-western England, to handle complete control schemes, and to manufacture special purpose control valves to users' specifications. I gather that Holland will be mainly concerned with running the works, and producing special-purpose valves.

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processing information

HUNTLEY

KENNY

LA COSTA

HARE

DILGER

The computer is very much in the news at the moment and so I was not really surprised to hear that Adrema Ltd are setting up a Data Processing Division which will eventually be based at their new factory in Cosham, Portsmouth. **Keith G. Huntley** who has just been appointed Adrema's Chief Electronics Engineer will be responsible for forming and building up the Division which will, I gather, be concerned with such products as the Farringdon electronic reading machine, the Productograph plant programmer (see *Control in Action*, August, 1961), electronic calculators, and so forth. An ex-E.M.I. television man, Huntley became chief electronics engineer of Rank Precision Industries in 1956, was concerned with developing the Rank Xerox and, I am told, conceived and developed the Xeronic high-speed computer-output printer.

Honeywell Controls set up their Electronic Data Processing Division in May, their intention being to market, and eventually manufacture, the '400' and '800' computers of their American parent concern Minneapolis-Honeywell Regulator. Now I learn of four new appointments to the d.p. Division. **L. Dilger**, who was at one time Research Manager at Nash and Thompson and, more recently, Group Leader of S. Smith & Sons' Computer Department, becomes Technical Sales Manager; **M. Hare**, at one time an accountant, and later Head Programmer at Glaxo Laboratories, is Manager, Applied Programming; **J. Kenny**, who handled I.C.T.'s continental computer interests, becomes Manager of the E.D.P. Centre, and will also be in charge of a Honeywell European E.D.P. Centre which is to be established soon; and **H. La Costa**, a chartered accountant and previously I.C.T.'s Manager in north-east England, becomes Commercial Sales Manager.

A.E.I. have appointed a Director of Research, **L. J. Davies** who was Director of Research of A.E.I. (Rugby). Davies is thus responsible for the A.E.I. research establishments at Aldermaston (**Dr T. E.**

Allibone), Manchester (Dr **J. M. Dodds**), Harlow (Dr **M. E. Haine**), and Rugby (Dr **J. E. Stanworth**—taking over from Davies). The new Director of Research reports to the A.E.I. Board through Sir **Cecil Dannatt**, the Vice-chairman, and becomes a non-executive Director of A.E.I. (Rugby).

All this A.E.I. news reminds me that Sir **Willis Jackson**, who was Director of Research and Education at A.E.I. (Manchester)—still called Metropolitan-Vickers by some—has just taken the Chair of Electrical Engineering at Imperial College.

Well known in the hydraulics world, **D. F. Denny** has been appointed Chief Engineer of Ronald Trist & Co., the boiler and liquid-level control firm Denny was with the British Hydromechanics Research Association, and Chief Technical Executive of Pratt Precision Hydraulics.

AUTHORS IN CONTROL

M. V. Wilkes (*Design of practical self-repairing computer systems*, page 86) took the Mathematical Tripos (Wrangler) at St. John's College, Cambridge, and did research in the Cavendish Laboratory while a University Demonstrator. During the war years he was concerned with radar and operational research, and in 1945 was a University Lecturer and Acting Director of the Mathematical Laboratory, Cambridge, becoming Director in 1946. A Fellow of the Royal Society, Dr Wilkes, who was a member of the I.E.E.'s Measurement and Control Section Committee during 1956–59, and President of the British Computer Society from 1957–60 is *Control*'s consultant on computers and data processing.

P. G. Corrin (*Input-output techniques in computer process control*, page 89) graduated in natural sciences from St John's College, Cambridge, in 1954. He joined the Royal Aircraft Establishment, Farnborough, and carried out missile studies on the Tridac analogue computer, subsequently being engaged on the design of a digital differential analyser and a study of its application to simulator techniques. He left the R.A.E. in 1960 and joined the Process Control Division of Ferranti where he is now concerned with industrial applications of Argus digital computer systems.

CORRIN

DEMCZYNSKI

S. Demczynski (*Production control and machine loading in a jobbing shop*, page 94) graduated from Polish University College, London, in 1951, and then spent four years in the Great Baddow, Essex, Research Laboratories of Marconi's Wireless Telegraph Co. Ltd. He joined de Havilland Propellers as a senior engineer in 1955 and was engaged on research into control systems for guided weapons. In 1958 he became a Deputy Leader of a team developing an integrated data-processing system employing a large digital computer. He is now in charge of de Havilland's operational research section. Demczynski is the author of several papers on servo-mechanisms and on commercial applications of digital computers in business.

Andrew D. Booth (*Progress in automatic language translation*, page 103) experienced some years in industry and graduated with first-class honours as an external student of the University of London. During the war he was at Birmingham University working on crystallographic problems of explosives. In 1946 he took up a Nuffield Fellowship at Birkbeck College, London, and in 1947 spent six months at Princeton, U.S.A., as a Rockfeller Fellow and a member of the Institute for Advanced Study. On returning, he initiated the Birkbeck College Electronic Computer Project, and in 1954 became the Director of the Computation Laboratory, Birkbeck College, and University Reader in Computational Methods. In 1957 Dr Booth was appointed Director of the, then, newly formed Department of Numerical Automation.

R. J. A. Paul (*The state of analogue computation*, page 106 and *Computers—Control survey 22*, facing page 116) is a first-class honours graduate of London University. For six years he was a research engineer at the Motor Industry Research Association, where he was mainly concerned with measurement and instrumentation techniques. He spent two years at Sperry Gyroscope working on the control aspects of a guided missile project, and four years with Short Brothers and Harland. Paul was Head of the Electronics Section of Short's Research Department, and responsible for a number of projects including the Short computer and control systems for guided missiles. He is a consultant to Short's For the past four years he has been Deputy Head of the Electrical Engineering Department of the College of Aeronautics, Cranfield.

J. H. Westcott (*New guide to adaptive control*, page 108). See page 129, May 1961.

Denis Taylor (*Talking about automation*, page 109). See page 128, July 1961.

J. W. Dalton (*Rapid compensation for changes of mains voltage in a furnace controller*, page 110) studied electrical and mechanical engineering at Northampton and Battersea Polytechnic Colleges. He has been employed as a switchgear engineer at British Thomson-Houston and at English Electric, and is now on the staff of The Electrical Research Association. A M.I.E.E., he has recently designed equipment for the Association's new creep-of-steel testing laboratory.

PAUL

DALTON

J. Martin (*Null balance instrument for accurate determination of gas density*, page 111) says that his experience in the R.A.F. as Wireless Operator/Air Gunner gave him a taste for the technical life, so he studied electrical engineering in the evenings at Woolwich Polytechnic. He worked for Standard Telephones and Cables, Cintel and Technograph Electronic Products before finding a suitable niche with the Instrumentation Department of the Distillers Company. Martin is also involved with Martin-Clark Instruments in the design of soil-resistivity instruments for archaeological use.

F. T. C. Doughty (*Control valve for slurries*, page 112) is a mineral dressing engineer who has specialized for many years in the design of dense media plants. He was closely associated with the first plants of this type to be built in Europe. In this work Doughty was involved in the handling of high-density slurries and he has recently been concerned with the design and operation of valves for the control of such slurries. He is now Managing Director of Neldco Processes Ltd and Neldco Safety Equipment Ltd, both of Bracknell, Berkshire.

P. G. Morgan (*Data Sheet 24: Definition of an equivalent time constant*, page 117) graduated as an external student of London University in 1949 and was trained practically in the Royal Dockyards at Portsmouth and Devonport. After a period at the Admiralty he joined the staff of the Engineering Department at Manchester University.

New for the user

A monthly review of instruments, components, equipment and machinery for automation

For further information, circle the appropriate number on the reply card facing page 164

PRESSURE ALARM

automatic or manual reset

The pressure-indicating system of an alarm by West Instrument consists of a Zener-diode voltage regulator which excites a strain-gauge transducer; this feeds a high-resistance indicating meter with a linear pressure-scale.

Facilities are provided for connecting

Manual or automatic reset

to an external visible or audible alarm system, and a switch selects either manual reset—in which the circuit cannot be reset until the pressure is below that desired—or automatic reset. It is claimed that calibration of these instruments to the transducers is simple, and well within the capability of a machine operator.

Circle No 501 on reply card

PROCESS CONTROL UNIT

two-term pneumatic

Honeywell's Batch-Air-O-Line is designed to counteract overshoot on start-up of the control system. Operation is as follows: when the process is shut down, the controller output increases. When it reaches 15 lbf/in^2, a bleed valve opens to exhaust the accumulated air, and the proportional band is simultaneously shifted downscale by blocking off the integral chamber. The controller output thus stays saturated during shut-down. On restarting, the integral chamber exhaust is shut, and air returns to the integral chamber, reducing the controller output. The proportional band gradually shifts upwards, and set point is reached without the usual cycling. It is claimed that this technique does not slow the response of the process; the approach to the set point is simply made more gradual on start-up. **Circle No 564 on reply card**

DATA SELECTOR

up to ten output-channels

Ultra's UE 875 data selector allows blocks of information encoded on paper tape, magnetic tape or punched cards, to be selected and routed to up to ten output-channels. Up to 64 lines are available on each output channel—sufficient to operate a full typewriter keyboard. The output channels will also operate add/list machines, paper-tape punches etc.

Selection of data is achieved by inserting selection characters between successive blocks of information fed into the unit, up to 99 such characters being available. The information required for any particular output-channel is selected by the appropriate code selection switch on the front panel. The input signals

Tape or card input

are decoded by a matrix mounted on slide-in printed-circuit boards which can be in combinations to accommodate any 5-, 6-, 7-, or 8-hole code.

Circle No 554 on reply card

PHASE METER

wide frequency range

Airmec's type 281 phase-meter will operate over the frequency range 0·01 to 1000 c/s. Within this range accuracy is claimed to be $\pm 3°$, and a reading may be obtained in one cycle of the input voltage.

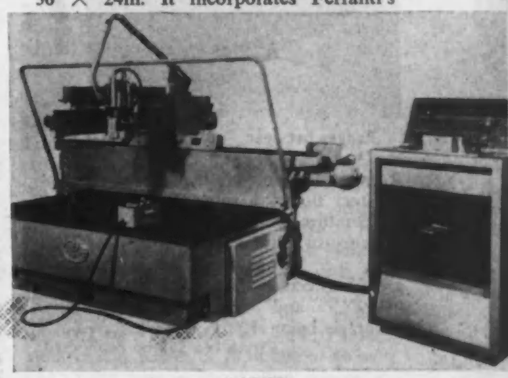
The unit requires reference in-phase and quadrature inputs to generate the circular time-base. The unknown input may be from 1V to 300V peak, and facilities are provided for cancelling out the d.c. component by use of an injected bias voltage. Supply required is 100–125V or 200–250V, at 50 c/s.

Circle No 556 on reply card

AUTOMATIC MEASURING MACHINE

three dimensions

A machine developed by High Precision Equipment in co-operation with Ferranti is capable of inspecting such things as template shapes, and three-dimensional forms such as aerofoils and large castings, within an overall capacity of 72 $\times$ 36 $\times$ 24in. It incorporates Ferranti's



Accuracy 0·00025in

numerical positioning control on the horizontal axes of measurement, and a specially designed system in the vertical axis. A continuous display of position on all three axes is provided. Accuracy of readings is claimed to be 0·00025in.

Circle No 558 on reply card

DUST MEASURING EQUIPMENT

non-optical system

A.E.I.'s dust-measuring equipment uses a system which eliminates errors due to flue-gas velocity which are inherent in optical methods, but takes into account the product of particle area, velocity and number.

A continuously-flowing sample of the gas is provided with a corona environment, where all solid particles become electrically charged, the charge being proportioned to a surface area. The charge on the particles collected pro-

duces a current proportional to the product of particle number, area, and flow. After amplification, this current may be used to indicate or record the level of pollution. Dust build-up in the equipment is prevented by automatic purging with air for a few seconds every twenty minutes.

The equipment is sufficiently sensitive to respond to particle diameters down to 0·01μm, and will monitor flue-gases leaving dust-arresting plant of large boilers with burdens of about 0·4 grains/ft^3 during soot blowing.

Circle **No 508** on reply card

ON-OFF TEMPERATURE CONTROLLER

two-in-one

A mercury-in-steel controller, the model 1039, having independent circuits allowing control at two points through one instrument is available from British

Ranges between -20°F and $+1000$°F

Rototherm. Each of the circuits consists of steel Bourdon tubes, capillaries, and temperature-sensitive bulbs, operating mercury-switches rated at 30A, 230–250V a.c. Temperature ranges available are between -20°F and $+1000$°F (-29°C and $+555$°C), minimum coverage being 100°F (55°C).

Circle **No 555** on reply card

D.C. AMPLIFIERS

low drift without chopper

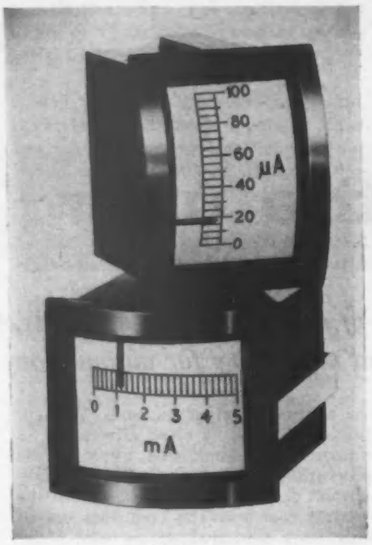
A transistorized d.c. amplifier by Fenlow Electronics, the A.101, has an input impedance of 13kΩ, and gain readily adjustable from four to several hundred by changing an external feedback resistor. Band-width at a gain of twenty is approximately 1 kc/s. The output is $\pm$30V into a 20kΩ load, or rather less into loads down to a 5kΩ minimum. A typical drift-figure, for indoor conditions, is 5 mV/h, and the ambient-temperature range is 10 to 55°C. Power supplies required are $+36$ and -36V d.c., with a peak current of 40 mA/line.

Circle **No 561** on reply card

EDGWISE METERS

vertical or horizontal

A series of measuring instruments by Pullin have 1in scales in either the vertical or horizontal planes. They



Miniature

measure $1\frac{13}{32} \times 1\frac{1}{4}$in, with a back depth of under 2in, and weigh about $2\frac{1}{2}$ ounces. Ranges available are 50mA to 500mA, and voltages up to 500V d.c. These miniature instruments are housed in phenolic resin cases, and are said to be completely proof against dust and water splashes.

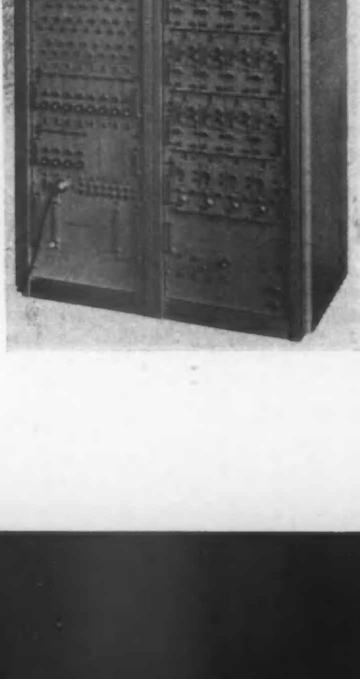
Circle **No 563** on reply card

TAPE RECORDER

up to sixteen channels

Six tape-speeds from $1\frac{7}{8}$ to 60 in/s are provided on Epsylon's MR 210 recorder; capacity is 4800ft of standard tape, start time at 60 in/s is 3s, and stop time for

Six speeds



all speeds is less than 1s. Up to sixteen recording channels using either in-line or interleaved heads can be supplied.

Frequency response for f.m. recording is d.c. to 10 kc/s at all tape-speeds; for direct recording, range is 50 c/s to 2·25 kc/s at $1\frac{7}{8}$ in/s, and 200 c/s to 70 kc/s at 60 in/s. The unit will function from any standard a.c. mains supply.

Circle **No 553** on reply card

AUTOMATIC CAPSTAN LATHE

plug-in programming

The Dowding and Doll Accuratool automatic lathe is set by selecting feed- and speed-values and slide movements by plug-in connexions on an electrical control panel.

The set-up can quickly be changed from continuous-cycle for bar work to single-cycle for chuck work, and movements can be programmed to take place

Bar capacity $\frac{11}{16}$in

simultaneously, or in simple or overlapping sequence. Collet opening and closing, turret-slide movement, cross-slide movement, turret-slide feed, motor speed-change, reverse and stop, are automatically controlled, and a spindle brake is provided if required. The control panel is provided with two sets of electrical sockets, one set connected to the power and the other set to solenoids controlling the machine movements, any of which can be actuated by plugging in the appropriate connexion. On completion of each movement signals transfer the power to the next step and, by linking the sockets, movements can be kept in operation as long as necessary; time delays can be introduced on any step to provide tool-dwell.

Bar capacity is $\frac{11}{16}$in, centre height being $5\frac{1}{4}$in. The spindle bore is $\frac{27}{32}$in and the turret-slide stroke is 3in. There are sixteen spindle-speeds in four overlapping ranges, covering 37 to 3000/min, and the two-speed motor is rated $1\frac{1}{2}$-$\frac{3}{4}$ hp.

Circle **No 509** on reply card

TRANSISTOR TEST METER

leakage and characteristics

A low-priced universal transistor leakage-test and characteristic meter is available from Grundy and Partners. At a p.d. of 4·5V, this unit will measure collector-emitter and collector-base leakage

Universal

current, and current gain on transistors up to 800mW. Base input current may be varied through a preset range of 10, 50, 100, and 500mA; a push-button switch allows any selected base current to be increased by 10%. Diodes are tested at forward currents up to 10mA, depending on forward resistance; reverse current is checked at a potential of 9V.
Circle **No 562** on reply card

FOUR-WAY AIR VALVE
solenoid operated

Series A air valves by Alcon will operate from vacuum to 200 lbf/in^2. A feature of these valves is the low current required to operate the solenoid: inrush is 0·95A, holding current 0·25A; voltage required is 230V, 50 c/s, but other coils may be supplied to order. Maximum frequency of operation is 180 c/min, and leakage is claimed to be very low despite ease of movement. Circle **No 518** on reply card

RECORDING METER
voltage and current

A portable unit by Norma (Austria) measures direct voltage and current from 60mV to 600V and 15mA to 6A respectively, and alternating voltage and current from 30V to 600V and 15mA to 6A respectively. Four clockwork drives for the strip-chart are available, covering, in all, speeds from 5 to 14,400 mm/h; at the slowest speed, time between windings is about 32 days. The meter will measure a.c. from 15 to 100 c/s, and the accuracy for a sine-wave input is ±1·5% full scale. The model 431 is available in the U.K. from Croydon Precision Instrument.
Circle **No 515** on reply card

DATA TRANSMISSION SYSTEM
fast, accurate

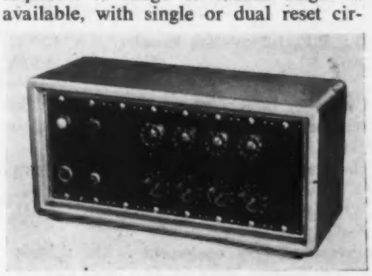
I.B.M.'s 1001 data-transmission unit is intended for accurate reporting from information sources within a private network to a central point. It has a ten-digit keyboard, and a card carriage with fixed 80-, 51-, or 22-column feed. The sender dials the number of the receiving card punch on his telephone, to which the 1001 is attached; a signal indicates that the punch is ready to receive. A card is inserted into the carriage and data from the first 21 columns are transmitted at 12 columns/s. The sender then keys-in variable information which is simultaneously transmitted. When the register key is pressed the card is released, and a signal from the receiver indicates that the data have been received in punched-card form, ready for immediate input to the central data-processing system.
Circle **No 503** on reply card

TRANSISTORIZED DIGITAL COMPUTER
desk size

The 160-A computer, by Control Data Corporation (U.S.A.) has a magnetic-core memory of 8192 words, expandable in modules up to 32,768 words, the core having a total cycle-time of 6·4μs, and an access time of 2·2μs. Other features include the buffered input and output, automatic and independent of the main computer program, and the 'manual stop', program interrupt, and a list of 91 instructions.
Circle **No 505** on reply card

ELECTRONIC COUNTER
up to 500,000 pulses/s

Available from Britec is the Elesta IZ.301 counter, using EZ.10B decade counter-selector tubes. Two models have six and eight sub-units respectively: these consist of input, coupling, and output stages as required. A range of decade stages is available, with single or dual reset cir-



High count-rate

cuits, for batching any predetermined number up to 100,000/s. Operating voltage, at 50c/s, is 220V a.c. ±10%. Consumption of the eight-stage counter is 50VA max.
Circle **No 504** on reply card

QUICK LOOKS

Valves. A range of solenoid- and pilot-operated valves from $\frac{1}{4}$in to $1\frac{1}{2}$in B.S.P. is now made by T.A.L. Numatics. All have stainless-steel spools and sleeves, and may be changed from solenoid to pilot operation and *vice versa*. Solenoid-operated valves in this series are all actuated by a 2W heavy-duty solenoid.
Circle **No 513** on reply card

Signal generator. Airmec's type 252 low-frequency generator uses a Wien-bridge oscillator with thermistor feedback amplitude-control, and provides a sine-wave output covering 30 c/s to 300 kc/s in four ranges. Calibration accuracy is quoted as ±1%, ±1 c/s, and frequency stability (long-term) as better than 0·1% ±1 c/s over the entire frequency range. Harmonic distortion is less than 1% up to 100 kc/s, and less than 2% from 100 to 300 kc/s; maximum output is 100mW into 600Ω, or 15Vr.m.s. open circuit.
Circle **No 514** on reply card

Medium pressure switch. A variable-differential pressure switch, the 108V, has been added to the range made by Bailey and Mackey. The range of differential adjustment is from standard differential to 95% of the working pressure,

the accuracy of the differential being within 1% of the maximum pressure. The switch is a single-pole change-over unit, with one contact normally open and one normally closed.
Circle **No 560** on reply card

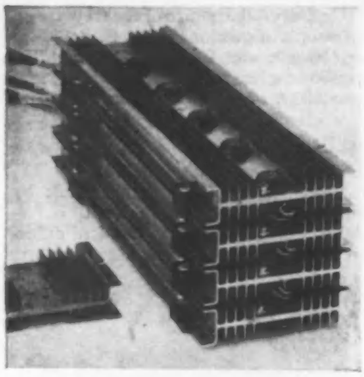
Co-ordinate table. Designed by Dowding and Doll for mounting on the bed of a radial drill, the Atlantic co-ordinate table is controlled by Ferranti electronic numerical positioning equipment, using punched tape. Positional accuracy is independent of the leadscrews; the system uses diffraction gratings which give an accuracy within ±0·0002 in/ft, and settings are repeatable to within ±0·00025in. Traverse is simultaneous along x and y axes of the table at 60 in/min; table size is 36 × 30in, giving a drilling area of 30 × 24in.
Circle **No 510** on reply card

Continuous weigher. A continuous electronic weigher by Craven Electronics is intended for weighing and recording the weight of material carried on a conveyor belt. This is presented on a counter in any required weight-units. The unit is claimed to be accurate to within 0·5%.
Circle **No 512** on reply card

Automatic assembler. A transfer machine by U.S. Industries consists of an arm and an actuator which can be fitted with many types of fingers and jaws, all controlled by an electronic computer. With the aid of an accessory swivel the Transferobot 200 acquires a 'wrist', allowing it to perform a wide variety of motions within the limits of its reach. Price of this machine in the U.S.A. is about £900.
Circle **No 559** on reply card

Heat sinks. A range of heat sinks for mounting transistors is available from

New for the user



Invar (U.S.A.) Theses are stack-mounted on insulators, and feature a variety of mounting-hole patterns which fit most common power transistors. Three-inch lengths with four of the common hole-patterns are available from stock.
Circle **No 506** on reply card

Capacitors. A range of close-tolerance polystyrene capacitors is available from Plessey. These may be encapsulated, which reduces heat-deformation and allows them to be used at temperatures up to 85°C. Capacitance range is 10pF to 0·22μF, but non-encapsulated capacitors in the range are available with higher values. Working voltages for either type are from 125 to 1000V, but encapsulated types are made for operation at 2000V.
Circle **No 511** on reply card

Analogue-to-digital converter. Digital display for their model-3 Multiverter is announced by Packard Bell (U.S.A.), The unit provides three decimal digits plus sign. Conversion accuracy is given as 0·05% ±half least-significant bit, with an operating rate of 8000 conversions/s for decimal output.
Circle **No 502** on reply card

Vacuum switch. Designed for switching in high-voltage pulse-forming networks, Ferranti's 13VSB1 allows pulse-length to be changed easily. Maximum ratings are as follows: pulse voltage, 15 kV; pulse current, 100A; operating time, 5ms; output resistance (closed) 0·02Ω; capacitance between contacts (open) 1·5pF. The solenoid is rated at 24V d.c., resistance being 20Ω ±10%; pull-in and hold currents are 1A and 100mA respectively.
Circle **No 519** on reply card

Motors. The first models in a range of fractional horsepower a.c. motors are now available from Comtex. Made to B.S. 2757, class E, they are the GL8 (motor only), GL9 (with single-reduction gear-box), and GL10 (with double-reduction gear-box). Rating is $\frac{1}{30}$hp at 1400 rev/min (nominal), and they can be supplied for operation from 50 or 60 c/s supplies at 100–110V, 200–220V, 230–250V, single phase, and 400–440V three phase.
Circle **No 557** on reply card

Plug-in follower amplifier. Model K2-BJ, made by Philbrick (U.S.A.), is a rugged military version of their K2-BI. It has an octal plug-in base, making it compatible with other amplifiers in the range. Used as a booster for operational amplifiers it provides an output of 20mA at ±100V, a gain of about 0·8, and has an output impedance of 250Ω before feedback.
Circle **No 516** on reply card

Ferrite-core memory. The RQA is an addition to the series-R memories by Ampex (U.S.A.). It has a 5μs memory cycle, with 2μs access time and 2·5μs buffer time. Standard word-capacities range from 1024 to 32,768, available in 8- to 60-bit word lengths. Operating modes are random access with clear/write, read/regenerate cycles, or load and unload half-cycles. The unit will operate over a temperature range from 0 to +50°C, with humidities up to 95%.
Circle **No 517** on reply card

PUBLICATIONS RECEIVED

United Kingdom Atomic Energy Authority Seventh Annual Report 1960–61. *U.K.A.E.A. 1961. 80 pp. 5s.* ★520

An introduction to computational methods *by* **K. A. Redish.** *The English Universities Press Ltd. 1961. 211 pp. £1. 10s.* ★521

Reliability of protective systems for zero energy reactors *by* **D. Wray** *and* **M. J. Cowper.** *U.K.A.E.A. 1961. 15 pp. 2/6d.* ★522

Radioisotope applications engineering *by* **J. Kohl, R. D. Zentner** *and* **H. R. Lukens.** *D. Van Nostrand Company Ltd. 1961. 562 pp. £4. 4s.* ★523

Theory of traffic flow *by* **R. Herman.** *D. Van Nostrand Company Ltd. 1961. 238 pp. £3. 4s.* ★524

Writing a technical paper *by* **Menzel, Jones** *and* **Boyd.** *McGraw-Hill Book Company, Inc. 1961. 132 pp. 15s.* ★525

Bulletin of special courses in higher technology 1961–62 Part 1: Autumn term. *London and Home Counties Regional Advisory Council for Technological Education. 1961. 128 pp. 3/6d.* ★526

An introduction to the properties of engineering materials *by* **K. J. Pascoe.** *Blackie & Son Ltd. 1961. 295 pp. £1. 15s.* ★527

Digital Data *by* **D. S. Evans.** *Hilger & Watts Ltd. 1961. 82 pp. 15s.* ★528

D.E.R.E. Information Booklet. *U.K.A.E.A. 1961. 60 pp.* ★529

Queues *by* **D. R. Cox** *and* **Walter L. Smith.** *Methuen. 1961. 180 pp. £1. 1s.* ★530

The mathematical theory of linear systems *by* **B. M. Brown.** *Chapman and Hall. 1961. 267 pp. £2. 10s.* ★531

Oxygen analysis equipment is the subject of specification sheet SS 016 from George Kent. ★532

By-pass flowmeters by Brooks (U.S.A.) are described in their bulletin No. 116. ★533

Thickness gauge. Dawe Instruments' 1103 transistorized ultrasonic thickness gauge is described in a recent leaflet. ★534

Panel instruments with clear fronts are listed in a leaflet from Sangamo Weston. ★535

'The Staveley Express'. First number of a house journal for the staff of Staveley Industries. ★536

'European Electronic Data Processing' is the title of a report published by Auerbach Electronics (U.S.A.) ★537

Push-button keys by T.M.C. are described in a recent leaflet. ★538

'Survey of a chemical group'. A comprehensive illustrated account of the activities of the Albright and Wilson Group. ★539

Rotary switches by Austinlite are described in '*Simplified switching*', a 50-page booklet. ★540

'Cabinets for electronic equipment': a 16-page publication from Hassett and Harper. ★541

Engineering laboratory equipment by Griffin and George is detailed in a 90-page illustrated catalogue, publication No. P2122. ★542

Company guide: descriptions of the home and overseas companies of Stone-Platt Industries. ★543

Totally-enclosed fan-cooled cage-rotor motors by Lancashire Dynamo and Crypto are detailed in leaflet SL. 2. ★544

Metal-ceramic brazed seals are described in a pamphlet from Lodge. ★545

Amplifiers and other equipment by W. Bryan Savage are described in an illustrated booklet. ★546

Heat-transfer medium. I.C.I.'s Thermex is the subject of a 12-page booklet. ★547

Spectrometer. Elliotts' process mass spectrometer is the subject of bulletin 21620 ★548

Leakproof ball-valve. Hindles' B15 fluon-seated valve is described in catalogue-section A3. ★549

Motor control centres by G.E.C. are the subject of technical leaflet No. 445. ★550

Surge arrester valve. The Golden Anderson (U.S.A.) cushioned surge arrester is described in leaflet W-16. ★551

★ Circle the relevant number on the reply card facing page 164 for further information

Book Reviews

Relays

Static relays for electronic circuits *edited by* **Richard F. Blake.** *Reinhold/Chapman & Hall Ltd. 1961. 198 pp. £3 3s.*

The title of this book may well prompt the question, 'What is a static relay?' The editor in his preface provides the following answer: 'a static relay is an integral packaged unit marketed as a component to perform a relay like function. Some authorities add the requirements of (1) snap action, (2) electrical isolation between control and contact elements, and (3) no crosstalk between control and contact circuits'. Static relays avoid many of the inherent problems of mechanical relays, such as contact bounce, and usually have extremely fast response, long life, and high resistance to shock and vibration. The editor goes on to remark that the static relay is now in the transitional period between initial development and general acceptance. As more information about applications is disseminated, and as production costs are reduced, the static relay will undoubtedly become one of the basic components regularly used by the equipment designer.

The book is based on papers given at a conference and as a result there is some overlapping. However, in the early stages of a new subject this is all to the good, and I found the book very refreshing; each author feels that he is on to something good, and writes about it from his own angle.

A good half of the book is about static relays as defined above; the rest deals with switching circuits of the relay type, but with less emphasis on the design of a self-contained packaged unit. The first chapter surveys the static relay concept, and the second chapter contains a review of semiconductor regenerative switching devices There follows a technical specification for static relays from a U.S. Army laboratory; this has the smell of dusty official corridors, but is a contribution none the less.

Figs. 1 and 2 taken from the book, and reproduced here, may help the reader of this review to understand the static relay concept. In the circuit of Fig. 1 use is made of a blocking oscillator, the output of which is rectified and used to control a switching transistor. VR1 is a Zener diode and, when the input voltage exceeds the Zener voltage by approximately 0·4 volts, the gain of transistor Q1 increases until the loop gain exceeds unity and oscillations are produced. The resulting signal induced in the secondary of the transformer is rectified by the diode CR1 and the switching transistor Q2 is driven well into saturation. Fig. 2 shows a very different system using a lamp and a photocell. When a voltage is applied to the input the lamp L begins to glow and the resulting output from the silicon junction type photocell C switches on the transistor T. With suitable choice of components, a static relay of this type can be made to have an operating time as short as 5ms.

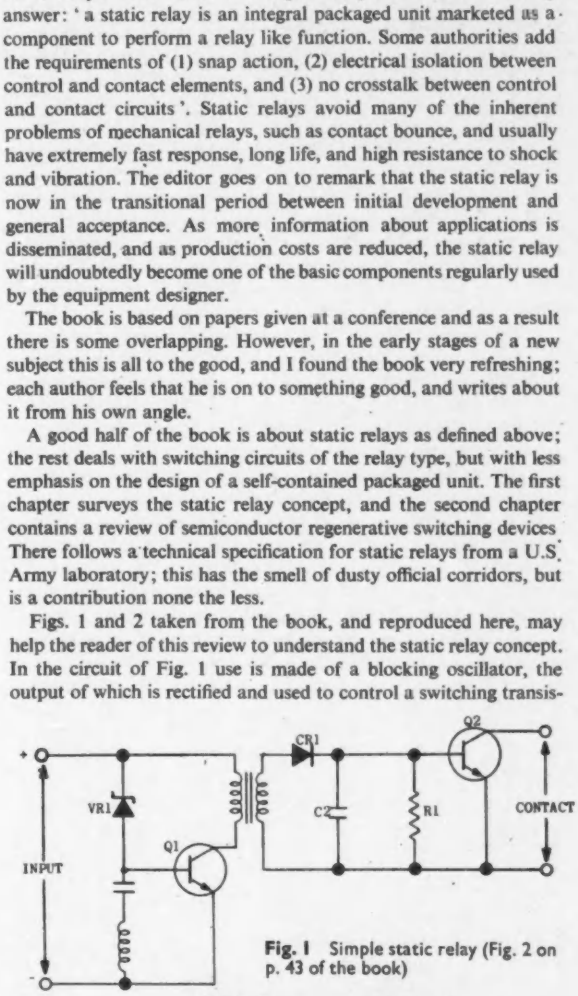


Fig. 1 Simple static relay (Fig. 2 on p. 43 of the book)

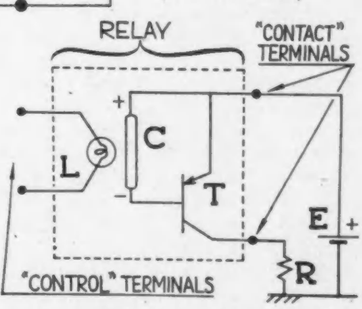


Fig. 2 Another simple static relay (Fig. 1 on p. 59 of the book)

I much welcome the appearance of this book, since it appears to me that ordinary mechanical relays are not nearly reliable enough for many control applications, and yet their convenience and adaptability are such that it is hard for a designer to avoid using them. Mechanical relays are all right for use in applications where their operation is infrequent (such, for example, as repeating at a distance the operation of a hand-operated switch), but they are treacherous in applications which involve their clicking away automatically for long periods. Relays are typically subject to intermittent faults, and these can have disastrous consequences in control applications. The fact that telephone switching engineers have been able to live with relays has, I feel, much misled the designers of other types of equipment. In telephone switching there is always a human being who can start the cycle afresh if something goes wrong; in a control system the apparatus is on its own. Moreover, I understand from my telephone engineering friends that a serious number of telephone calls get lost, and it appears that even in this application relays are not as successful as they appear to be.

We are witnessing a steady trend towards the use of electronic switching circuits in place of mechanical relays, whether they are packaged to form 'static relays' or not. The area in which this is a practical proposition is growing steadily. All control engineers those already on the band wagon, those about to jump on, and those who have only just realized that it is coming, will find much improving reading in this book. M. V. WILKES

Analogues

Analogue Computers *by* **I. I. Eterman.** *Pergamon Press Ltd. 1960. 264 pp. £2 10s.*

This book is a contrast in standards of material presented. That which falls within the compass of the electrical engineer is, if anything, over-simplified, and should present no difficulties to the reader who has attained H.N.C. level. The remainder of the book would appear to be in the province of the mathematician, and one is left to wonder whether the Russian writer is in fact a mathematician rather than an engineer. If he is the latter, then his knowledge of mathematics, for an engineer, is of a particularly high standard. So high, in fact, that engineering graduates in this country will find great difficulty in following much of this book.

One is subsequently left to ponder over the probability that the domination of American textbooks in this country is perhaps a bad thing. The standard American works on this topic cannot compare with this book so far as the application of analogue computers is concerned; which surely after all is the most important aspect, since such machines are no more than mathematical tools. How much more important it is, surely, to know how to solve a set of equations when some of the roots are in the right-half plane than to know which grade of paper is most suitable for the pen-recorder, after the *n* different varieties of which have been discussed at considerable length.

On reading this book one is left with the belief (mistaken, we trust) that the average Russian engineer speaks a language different from ours—metaphorically as well as literally!

Now a word about the presentation; the publishers apologize for the quality of production, and rightly so. Even allowing for

the fact that the book has been printed by photo-lithography, the numerous errors in the drawings, and the several omissions of the latter, certainly will not improve the reader's humour.

Finally, a word about the translation. This appears to be rather too literal, with the result that the Russian idiom comes straight through and is prominent on numerous occasions. The advice to budding translators must surely be: 'Read the classical translations of classical Latin and compare them with the literal, and realize the great improvement a free translation can achieve.' F. WALKER

Programming

Programming for Digital Computers *by* **J. F. Davison.** *Business Publications Ltd. 1961. 175 pp. £1 15s.*

This book is an introduction to the writing of programs for digital computers. At one time programming was thought to be a task mainly for mathematicians, but, with the wide use of present-day computers, it is now fair to say that much programming requires no great mathematical knowledge. The present book has been written with a correspondingly wider circle of potential readers in mind, and in my opinion an essentially readable and useful book has resulted.

Programmers, as a normal part of their training, learn a great deal about digital computers, but for the most part designers of digital computers do not pay sufficient attention to the problems of the programs. This book will make it possible for such designers to start filling that gap in their education. An easy book to read, it explains the programmer's task in the first three chapters, putting the subject into focus in terms of the whole subject of computers. Chapters 4 and 5 describe a small imaginary computer, which is sufficiently similar to a well-known commercially-available machine for many readers to recognize the resemblance. Chapters 6 and 7 describe more sophisticated programming techniques, including the use of parameters, subroutines, floating-point working, interpretive schemes and autocodes, whilst the final chapter describes some of the variations between the different types of digital computer, as well as the programmer's viewpoint on the various pieces of peripheral equipment such as card readers, and punches, magnetic tape decks and fast printers.

The book is well printed and written in sufficiently simple terms for easy assimilation, even by those readers who just want to find out what programming involves. DENIS TAYLOR

Methods of Feasible Directions *by* **G. Zoutendijk.** *D. Van Nostrand & Co. Ltd. 1960. 126 pp. £1 10.*

This book, which carries the subtitle 'a study in linear and non-linear programming', was the author's doctoral thesis presented in Amsterdam in 1960. After a theoretical introduction, the author describes several well-known methods of solving linear programming problems. The computational algorithms for these methods are then compared. The author's main purpose here is to present a collection of improvements to the product-form algorithm which together constitute what he names the 'revised product-form algorithm'. Under certain carefully stated assumptions, which are by no means applicable to all problems, he shows that this algorithm requires substantially less computation than the straightforward, the explicit-inverse, or the product-form algorithms.

The second half of the book is a theoretical study of a class of methods of solving general convex programming problems. These methods have in common that they start with a feasible solution, determine a feasible direction of advance which will increase the value of the solution, and then determine the length of the step to be made in that direction. As these methods are long-step gradient methods they tend to converge quite rapidly. They are formulated with the desirability in mind of being able to perform them on an electronic computer. Depending on the method of determining the direction of advance, several different 'methods of feasible directions' emerge. The author shows that upon simplification to linear or quadratic problems, some of these methods become identical with other well-known algorithms; so that this approach is a synthesis of one class of linear programming methods.

To anyone concerned with the solution of large linear programming problems, or interested in the more advanced theory of linear programming, this study is highly recommended; but it is unlikely to be intelligible to anyone not already acquainted with the elements of linear programming. The style of writing is concise and mathematical. It would have benefited greatly from a high standard of typesetting and layout. The method used, whilst legible and allowing the early appearance of this book, is rather more demanding on the patience and attention of the reader. MARTIN FIELDHOUSE

Signals

Fundamentals of Signal Theory *by* **John L. Stewart.** *McGraw Hill Publishing Co. 1960. 346 pp. £3 10s.*

This latest volume in the McGraw Hill *Electrical and Electronic Engineering Series* is, in spite of its somewhat deceptive title, primarily a mathematical textbook. The author has set himself the objective of separating the mathematics of networks from networks *per se*, so as to avoid much of the rather specialized jargon which tends to impair many textbooks on this subject from the standpoint of the reader who is not himself an electrical specialist. The author follows a line of development through the various mathematical models which have been devised for physical systems. He begins at the elementary level of electrical 'vectors' and the algebra of complex numbers, and passes through pole-zero concepts and the Laplace transformation to the consideration of discrete and continuous spectra using Fourier series and Fourier integrals. Although there is little that is new to the mathematically minded electrical engineer, the approach to and the general development of the subject is quite refreshing, and the book should be of considerable interest both to graduate students and to lecturers in a fairly wide field of the applied physical sciences.

I would particularly like to commend many of the very lucid explanations, particularly those of the graphical display of transfer functions and of the pole-zero concept. The illustrations are excellent and the equations are very well set out. There is, however, a rather surprising tendency to relegate to footnotes material which most readers would consider sufficiently important to deserve inclusion in the general text, and in one or two instances the footnotes amend rather than elucidate. In these last instances the reader, having found himself disagreeing with the main text, is somewhat disconcerted to find on referring to the footnote that he is at one with the author after all.

It is a little surprising also to discover that the Fourier transform is treated before the Fourier series, and it is disappointing to find yet another book perpetuating the dimensionally undesirable form of the Laplace transformation. This latter fact leads, amongst other things, to the usual distortion of the initial- and final-value theorems. The important differences between the significance of $0-$, 0, and $0+$, are, however, excellently brought out.

The references to other books and papers are sufficient to tempt the reader to enquire further into some of those aspects where the mathematics is not strictly rigorous. There is a generous number of problems at the end of each chapter, but the absence of answers may prove a drawback to the student working alone. Taken as a whole, this is a refreshing and stimulating book which may be read with profit by a fairly wide circle of mathematicians, physicists, and engineers.

H. GRAHAM FLEGG